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Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

SEMINAR ON CANADIAN POTASH MINING AND GROUND CONTROL

SÉMINAIRE SUR L'EXPLOITATION MINIÈRE DE LA POTASSE AU CANADA ET SUR LE CONTRÔLE DES TERRAINS

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DIVISION REPORT MRP/MRL 85-1(TR)

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RAPPORT DE DIVISION MRP/MRL 85-1(TR)

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SEMINAR ON CANADIAN POTASH MINING AND GROUND CONTROL

by

G. Herget*, J. Pathak*, M. Gyenge*, L. Geller*, G. Knight**, Y. Yu*
and M. Bétournay*

SUMMARY

The current ore recovery of potash in Saskatchewan is approximately 40%. This represents a significant loss of resources and causes a disproportionate increase of mining costs per ton from development and long underground transportation routes.

To address some of the problems connected with a potential increase of ore recovery, a two-year research program was funded under START (Short Term Assistance in Research and Technology) by the Government of Canada.

Eight contracts were initiated and let in the areas of regional mine stability; world review of mining options for potash; development of a two-dimensional finite element model for excavations in potash; testing of waste salt as mine backfill; assistance to establish a creep testing facility in Saskatoon; assessment of underground dust levels at workheadings; and two projects to evaluate excavation performance in the field.

The project has been actively supported by the following potash producers: Potash Corporation of Saskatchewan, Cominco Ltd., and Central Canada Potash. These companies control seven of the nine producing underground potash mines in Canada, and their support in related projects has amounted to $1 328 152.00 for the two-year period.

A contract progress and review meeting was held in Saskatoon, Saskatchewan on February 29, 1984, which showed that progress by contractors had been very satisfactory. A seminar was held on November 21, 1984, in Saskatoon, at which all mine operators in Saskatchewan were represented, along with representatives from government agencies and R & D establishments, with a total participation of some 50 persons (Appendix A).

At the seminar a questionnaire was distributed and the answers indicated that all of the participating mine operators wanted the research effort to be continued, with emphasis on backfill studies and development of instrumentation, especially brine locating devices.

Results from the research effort in the period 1983-1985 are available in executive summaries and final contract reports through CANMET, EMR and Micromedia Ltd., Toronto.

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et M. Bétournay*

RÉSUMÉ

Le taux actuel de récupération du minerai de potasse en Saskatchewan est d'environ 40 %, ce qui représente une perte importante de ressources et entraîne une augmentation disproportionnée des frais miniers par tonne pour la mise en valeur et les longues voies de transport souterrain.

Pour étudier quelques-uns des problèmes liés à une augmentation potentielle du taux de récupération du minerai, on a mis sur pied un programme de recherche de deux ans financé en vertu du programme START (Service temporaire d'aide en recherche et technologie) du gouvernement du Canada.

Huit contrats ont été adjugés dans les domaines suivants: stabilité régionale des mines; possibilités d'exploitation de la potasse dans le monde; mise au point d'un modèle bi-dimensionnel à éléments finis pour l'excavation dans la potasse; expériences d'utilisation du sel résiduel comme remblai dans les mines; aide pour l'établissement d'un laboratoire d'essai de fluage à Saskatoon; évaluation des teneurs en poussière souterraine dans les galeries d'avancement; et deux projets pour évaluer des excavations sur le terrain.

Le programme a été soutenu activement par les producteurs de potasse suivants: Potash Corporation of Saskatchewan, Cominco Ltd. et Central Canada Potash. Ces sociétés contrôlent sept des neuf mines souterraines de potasse au Canada, et leur aide dans des projets connexes s'est élevée à 1 328 152 $ en deux ans.

Une réunion pour faire le point sur l'avancement des contrats s'est tenue à Saskatoon (Saskatchewan), le 29 février 1984 et a révélé que les contractants respectaient assez bien leur calendrier. Un séminaire a eu lieu le 21 novembre 1984 à Saskatoon; tous les exploitants miniers de la Saskatchewan ainsi que les organismes gouvernementaux et les établissements de R-D y étaient représentés. Environ 50 personnes y ont participé (Annexe A).

À ce séminaire, un questionnaire a été distribué aux exploitants miniers participants, et les réponses ont révélé qu'ils désiraient tous que l'on continue les efforts de recherche en insistant particulièrement sur des études de remblayage et sur la mise au point d'instruments, spécialement des appareils pour déceler la saumure.

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Des résumés et les rapports finals des contrats présentent les résultats des recherches effectuées de 1983 à 1984. Des exemplaires sont disponibles au CANMET, à EMR et à Micromedia Ltd., Toronto.

FOREWORD

The seminar on Canadian potash mining and ground control concludes two years of support to the potash industry by the Federal Government of Canada under START.

No final solutions have been obtained for concerns affecting the potash industry, such as ground control and the need to look at alternatives to present mining methods. However, progress has been made in sharing information on ground control and mining experiences amongst operators, which is an essential step to improve expertise and assess the effect of mining on regional mine stability.

Gerhard Herget
Project Leader
Potash Mining

AVANT-PROPOS

Le Séminaire sur l'exploitation minière de la potasse au Canada et sur le contrôle des terrains couronne deux années d'efforts du gouvernement fédéral pour venir en aide à l'industrie de la potasse en vertu du programme START, acronyme de Service temporaire d'aide en recherche et technologie.

Aucune solution finale n'a été obtenue pour résoudre les problèmes touchant l'ensemble de l'industrie de la potasse tels que le contrôle des sols ou la recherche de nouvelles méthodes d'exploitation minière. Toutefois, des progrès ont été faits pour que les exploitants échangent des renseignements sur le contrôle des terrains et leur expérience minière, étape essentielle vers l'amélioration de leur savoir-faire et l'évaluation des effets de l'exploitation minière sur la stabilité régionale des mines.

Gerhard Herget,
Chef de projet,
Exploitation de la potasse.

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1. INTRODUCTION

The seminar on potash mining held on November 21st, 1984, at the Wills Inn in Saskatoon, Saskatchewan, had the following objectives:

1. To present to potash producers in Saskatchewan the findings from the 1983-85 contract research projects on potash mining, which had been promoted under START.

2. To create a forum between mining companies, consultants and government researchers, for a free exchange of ideas.

3. To identify research needs in ground control in order to enhance the competitiveness of the industry.

The START research program has been well received. At the beginning of the project, only 70% of the potash mining companies had showed any interest; however, at the seminar in November 1984, all operating potash mining companies sent at least one representative. In his concluding remarks W.E.G. Taylor, R & D Manager, PCS, stressed that CANMET is a very desirable vehicle through which to address problems common to the industry, because of its neutrality and its relatively large core of research staff and up-to-date facilities.

Prof. P.K. Kaiser, Edmonton, and Prof. M. Dusseault, Waterloo, presented a brief on facilities and present research work on soft and evaporite rocks at their institutions.

1. INTRODUCTION

Les objectifs du séminaire sur l'exploitation minière de la potasse, tenu le 21 novembre 1984 à la Wills Inn à Saskatoon (Saskatchewan), étaient les suivants:

1. Présenter aux producteurs de potasse de la Saskatchewan les résultats des contrats de recherche sur l'exploitation minière adjugés pour 1983-1985 en vertu de START (Service temporaire d'aide en recherche et technologie).

2. Fournir une occasion aux sociétés minières, experts-conseils et chercheurs du gouvernement d'échanger librement des idées.

3. Identifier les besoins de recherche en matière de contrôle des terrains afin d'améliorer la compétitivité de l'industrie.

Le programme de recherche START a été bien accueilli. Au début du projet, seulement 70 % des sociétés d'exploitation de la potasse s'étaient montrées intéressées; toutefois, au séminaire de novembre 1984, toutes les sociétés actives d'exploitation minière de la potasse ont délégué au moins un représentant. Dans sa conclusion, W.E.G. Taylor, directeur de la R-D, PCS, a insisté sur le fait que le CANMET est un des meilleurs véhicules auquel on peut recourir pour exposer les problèmes communs à l'industrie à cause de sa neutralité, de l'importance relativement grande de son équipe de chercheurs et de la modernité de ses installations.

Le professeur P.K. Kaiser d'Edmonton et le professeur M. Dusseault de Waterloo ont décrit les installations de recherche sur les roches tendres et les évaporites de leurs universités.

2. OPINION SURVEY AND EVALUATION

An opinion survey was conducted to identify priorities for future research work. The questionnaire is shown in Appendix A, and the responses are summarized in Table 1. The responses from mining companies, consultants, and the provincial governments of Saskatchewan and New Brunswick, are designated as "M", "C" and "P", respectively.

The highlights of the responses were:

1. All of the participants would like to see the research effort continued.

2. Seventy % of the mining representatives are prepared to participate in a research program.

3. Instrumentation development, especially brine locating devices, top the list of research objectives. Next in line are: studies on backfill, numerical modelling and shaft lining research.

2. SONDAGE D'OPINION ET ÉVALUATION

Un sondage d'opinion a été fait pour identifier les priorités des futurs travaux de recherche. Le questionnaire se trouve à l'annexe A et les réponses sont résumées dans le tableau 1. Les réponses des sociétés minières, des experts-conseils et des gouvernements provinciaux de la Saskatchewan et du Nouveau-Brunswick sont désignées par les lettres "M", "C" et "P", respectivement.

Il ressort des réponses que:

1. Tous les participants souhaitent que les efforts de recherche continuent.

2. Soixante-dix pour cent des représentants de l'industrie minière sont prêts à participer à un programme de recherche.

3. La mise au point d'instruments, spécialement d'appareils permettant de localiser la saumure, vient de loin en tête dans la liste des objectifs de recherche. Suivent des études sur le remblayage, la modélisation numérique et la recherche sur le cuvelage des puits.

Table 1 - Analysis of Opinion Survey - Nov. 21, 1984.

		Composition of returns:		
Total present:	47	Consultants	(C)	6
EMR employees:	13	Mining Companies	(M)	10
Opinions eligible:	34	Provincial Government	(P)	2
Returns received:	18			

	Yes			No			Undecided		
Evaluation (response in per cent):	C	M	P	C	M	P	C	M	P
Continue research effort	100	100	100	-	-	-	-	-	-
Would participate in R & D	100	70	50	-	10	-	-	20	50

	not needed			useful			Most desirable			undecided		
Specialty projects:	C	M	P	C	M	P	C	M	P	C	M	P
Backfill	-	-	-	50	20	100	17	70	-	33	10	-
Instrumentation	-	-	-	17	30	50	66	60	50	17	10	-
Brine location	17	-	-	33	20	50	33	80	50	17	-	-
Shaft lining	17	10	-	17	30	50	16	50	50	50	10	-
Numerical modelling	-	-	-	16	30	50	84	50	50	-	20	-
Subsidence	17	10	-	33	50	-	33	30	100	17	10	-
Mining method	17	10	-	-	10	50	33	50	-	50	30	50
Technology transfer:												
Summary report + microfiche	-	20	-	16	10	50	84	60	50	-	10	-
Mine site presentation	-	10	-	16	50	100	-	20	-	84	20	-
Specialty seminar	-	-	-	67	60	50	33	20	50	-	20	-

Other topics suggested: salt horse detection and rheological properties of evaporites

Tableau 1 - Analyse du sondage d'opinion - 21 novembre 1984.

Total présents:	47			Composition des répondants:								
Employés du EMR:	13			Experts-conseils			(C) 6					
Opinions admissibles:	34			Sociétés minières			(M) 10					
N° de répondants:	18			Gouvernement provincial			(P) 2					
				Oui			Non			Indécis		
				C	M	P	C	M	P	C	M	P
Évaluation (réponses en pourcentage)												
Continuer l'effort de recherche				100	100	100	-	-	-	-	-	-
Participerait à la R-D				100	70	50	-	10	-	-	20	50
Projets par spécialité:	Pas nécessaire			Nécessaire			Très souhaitable			Indécis		
	C	M	P	C	M	P	C	M	P	C	M	P
Remblayage	-	-	-	50	20	100	17	70	-	33	10	-
Instruments	-	-	-	17	30	50	66	60	50	17	10	-
Localisation de la saumure	17	-	-	33	20	50	33	80	50	17	-	-
Cuvelage des puits	17	10	-	17	30	50	16	50	50	50	10	-
Modélisation numérique	-	-	-	16	30	50	84	50	50	-	20	-
Subsidence	17	10	-	33	50	-	33	30	100	17	10	-
Méthodes d'exploitation minière	17	10	-	-	10	50	33	50	-	50	30	50
Transfert de technologie:												
Rapports sommaires + microfiches	-	20	-	16	10	50	84	60	50	-	10	-
Présentations sur les emplacements des mines	-	10	-	16	50	100	-	20	-	84	20	-
Séminaires spécialisés	-	-	-	67	60	50	33	20	50	-	20	-

Autres sujets suggérés: détection de l'aplite et propriétés rhéologiques des évaporites.

3. PRESENTATION AND DISCUSSION OF CONTRACTS

3.1 ALTERNATIVES TO PRESENT POTASH MINING IN CANADA

SCIENTIFIC AUTHORITY: J. Pathak

CONTRACTOR: Monenco $52 040

WORKSCOPE:

1. Review potash mining practice around the world (room and pillar, longwall, shortwall and barrier pillars, blasthole open stoping, and solution mining) with a description of geological setting, overburden thickness and quality, ground control concerns, production, productivity and costs.

2. Identify major parameters for and against use of alternative mining methods in Saskatchewan and New Brunswick.

3. Outline geotechnical program required before an alternative mining method can be implemented.

OBJECTIFS:

1. Étude des méthodes d'exploitation de la potasse dans le monde (chambres et piliers, longues, petites tailles et piliers de limite, trous de mine et chambres non remblayées, dissolution) avec des détails sur la configuration géologique, l'épaisseur et la qualité des morts-terrains, les problèmes de contrôle des terrains, la production, la productivité et les coûts.

2. Identification des principaux avantages et inconvénients d'autres méthodes d'exploitation minière en Saskatchewan et au Nouveau-Brunswick.

3. Description d'un programme géotechnique précédant l'emploi d'une nouvelle méthode d'exploitation minière.

RESULTS:

Mr. Angus Scott of Monenco presented the findings of this contract based on data from the following sources:

1. Mine visits

2. Questionnaires

3. Literature search.

The mine visits took place in Canada and the U.S.A. - six in the former, five in the latter. Forty-five questionnaires were sent to potash mining operations outside Canada, but only four responses were received. The literature search in 14 worldwide databases yielded 400 articles, of which 200 were relevant. Based on the above, the contractor outlined many points of interest under the following headings:

1. Review of potash mining methods, by country:
   Canada, France, Spain, Italy, U.S.A., West Germany, England, Brazil, U.S.S.R., East Germany.

2. Summation and breakdown of all mining methods used:

4	Mining Methods	Number of Mines	% of total
	Room and pillar - without depillaring	28	51
	Room and pillar - with caving	3	6
	Room and pillar - with backfill	4	7
	Shortwall	2	4
	Longwall	5	9
	Sublevel open stoping - with backfill	5	9
	Sublevel open stoping	3	6
	Cut and fill	1	2
	Block caving	1	2
	Solution mining	2	4
		54	100

3. Range of depths for potash mine operations:

		Depth (m)
Canada	Saskatchewan	960-1500
	New Brunswick	500-1000
U.S.A.	New Mexico	220-550
	Utah	800-1000
England		1150
West Germany		350-1200
East Germany		350-1100
France		850-1000
Spain		400-850
Italy		800-900
USSR		200-900

4. Interaction between mining method and deposit type:
   - Longwall mining in France, Soviet Union, U.S.A. for tabular orebodies.
   - Long room and pillar in tabular orebodies in the Soviet Union.

- Trackless mining, raises and ramps in salt dome mining, West Germany.
- Sublevel shrinkage stoping in the Soviet Union's steeply dipping deposits.

Chevron room and pillar mining in tabular orebodies in Saskatchewan and New Mexico.

- Solution mining in Utah, U.S.A.

5. Recovery percentage per mining method per panel:
   Example:

- Wyoming, U.S.A.	room and pillar	36%	extraction ratio
	drum miner	28%	" "
	longwall	81%	" "

6. Points for and against alternative mining methods.

7. Expectations and recommendations for alternative mining methods.

CONCLUSION:

The mining methods that warrant further study as alternatives to present Saskatchewan mining operations are shortwall mining and longwall mining with or without backfill. Additional details are given in Table 1-1 and the final report by the contractor.

DISCUSSION:

Dr. P. Mottahed of PCS inquired about the cost characteristics of different mining methods. The speaker answered that due to poor international response costs were not attainable. Mr. Scott added that costs could be estimated by comparison. Mr. D. Mraz of Mraz Project Consultants commented on the suitability of alternative mining methods; the availability and popularity of shortwall equipment and methods; the advantage of retreating from mined-out areas compared to advancing mining as practised in the present Chevron mining method. The drawback of shortwall mining lies in the use of backfill which requires a modification in present technology. Mr. D. Gladwin, R.P.O. CANMET, asked if various problems associated with potash mining, e.g., water in surrounding strata, had been taken into account when comparing the recovery ratios of various countries. Mr. Scott explained that all mining aspects had been looked at systematically. Water problems are found in many other countries, e.g., West Germany.

Table I-1 - Summary of principal characteristics of underground potash mines

Ref. Company, mine, location	Year of production	Total reserves (Mt)	Present prod. capacity (Mt K_2O/yr)	Present ore capacity (Mt ore/yr)	Average grade (% K_2O)	Depth (m)	Gradient (degrees)	Overall recovery (%)	Mining method	Total employees	Remarks
CANADA											
01 PCA - Penobsquis, NB	1984	-	0.7	2.3	25	460-470	25-45	55-60	Cut and fill	245	-
02 Denison - Saltsprings, NB	1985	230	1.0	3.6	28	835	12-20	60-65	R & P long, backfill	-	-
03 SP - Millstream, NB	(1988)	256	-	-	22	840-1200	5-70	23	R & P long, backfill	441	-
04 PCS - Rocanville, Sask	1971	-	0.78	3.0	27	960	0.2	33	R & P long	-	-
05 IMC - K1 & K2, Sask	1962/1967	-	2.32	9.3	25	955	0.2	35	R & P long	-	-
06 PCS - Cory, Sask	1969	-	0.83	3.2	18-26	1012	0.2	38	R & P long Chevron	-	-
07 PCS - Lanigan, Sask	1968	-	0.60	3.0	20-24.5	1006	0.2	-	R & P long	-	-
08 PCS - Allen, Sask	1968	-	0.97	3.6	27.3	1036	0.2	-	R & P chevron		
09 Cominco - Vanscoy, Sask	1969	112	0.50	3.6	25-30	1076	0.2	39	R & P long		
10 CCP - Colonsay, Sask	1969	-	0.82	3.1	22-32	1021	0.2	35	R & P chevron		
11 PCA - Saskatoon, Sask	1958	-	0.42	1.6	27	1016	0.2	-	R & P long		
12 PPG - Kalium, Sask	1984	-	0.85	-	-	1730	-	-	Solution		
UNITED STATES											
01 Kerr McGee - Hobbs, NM	1966	63.5	0.2	3.3	13-18	500	1.2	55	R & P chevron	388	
02 Mississippi - Carlsbad, NM	1931	290	0.2	2.6	14-33	260-500	1.7	-	Shortwall	406	on care and mtce
03 Amax - Carlsbad, NM	1953	-	0.5	4.1	11-19	220-340	1.1	-	Shortwall	-	
04 PCA - Carlsbad, NM	1934	10	0.5	3.1	12-23	305	0.8	70	R & P, dapillaring	396	
05 IMC - Carlsbad, NM	1940	-	0.3	-	10-14	215-270	1.0	-	R & P	-	
06 National Potash - Lea, NM	1957	-	0.2	-	14	490-550	1.0	-	R & P	-	
07 Duval - Nash Draw, NM	1964	37.7	0.1	-	8-16	274-328	1.1	-	R & P	-	
08 Texas Gulf - Cane Creek, UT	1965 (conv) 1970 (sol)	-	0.2	-	27	920	8.8	100	Solution	100	
SPAIN											
01 MPS - Suria, Catalonia	1926	-	0.3	1.8	16.5	550-680	60-70	-	Room and pillar	-	
02 UERT - Cardona, Catalonia	1930	62.5	0.25	2.5	11-12 12-20	1100	20-60	66	Sub-level open staping	680	
03 UERT - Llobregat, Catalonia	1934/1948	16.0	0.4	1.7	22.5	45	5-10	50	Long room & pillar chevron & backfill	-	
04 PDN - Esparza, Navarra	1963	-	0.325	2.8	13	200-1500	13	70	Longwall caving (advancing)	-	
UNITED KINGDOM											
01 ICL - Boulby, Cleveland	1973	-	0.48	1.7	25-30	1066	1 in 10	25	Room & pillar (D&B)	-	
ITALY											
01 ISPEA - San Cataldo/Palo, Sicily	1960 (sc) 1974 (p)	-	0.45-0.50	-	12 10-17	200	0-45	45	R & P	600	
02 ISPEA - Racalmuto, Sicily	1973	-	0.65	-	11	840	25	40	R & P (sublevel)	-	
03 ISPEA - Pasquasia, Sicily	1964	-	1.0	-	14.5	825 757 310	25-30	-	R & P Block caving	-	
04 ISPEA - Corvillo, Sicily	1967	-	0.2	-	15-17	-	-	-	R & P	-	
05 ISPEA - Milena, Sicily	U.D.	-	0.5	-	-	1250	-	-	-	-	
06 ISPEA - Realmonte, Sicily	1977	-	0	-	15-17	150	60-65	-	Staping	-	

FRANCE										
Mines de Potasse d'Alsace (MDPA)										
01 Amelie	1910	-		12.9	19	420-1100	up to 35	-	Longwall	-
02 Theodore	-1914	-	1.8	7.7	19	420-1100	up to 35	-	Longwall	-
03 Marie-Louise	-1914	-		14.5	19	420-1100	up to 35	-	Longwall	-
GERMAN FEDERAL REPUBLIC										
Kali und Salz AG										
01 Bergmannssegen - Hugo	-	-	0.21	1.81	11.5	350-1200	40-90	85-90	Open sublevel Stoping	-
02 Salzdetfurth	1900	-	0.25	1.96	12.5	770-900	40-90	85-90	"	-
03 Siegfried - Giesen	1906	-	0.12	1.13	10.8	1050	40-90	85-90	"	-
04 Sigmundshall	-	-	0.30	1.78	16.9	400-1040	40-90	85-90	"	-
05 Niedersachsen - Riedel	1910	-	0.15	1.12	14.0	750-1320	40-90	85-90	"	-
06 Wintershall	1903	-	0.44	6.1	11.0	540	2-3	70	R & P	-
07 Hattorf	1910	-	0.37	4.5	11.1	700-1060	2-3	55-65	"	-
08 Neuhof - Ellers	-	-	0.31	3.2	12.0	400-600	2-3	55-65	"	-
GERMAN DEMOCRATIC REPUBLIC										
Kalibetrieb Werra										
01 Unterbreizbach	-	-		-	-	-	-	50	R & P	-
02 Merkers	-	-	0.72	-	-	-	-	50	R & P	-
03 Dorndorf	-	-		-	-	-	-	50	R & P	-
Kalibetrieb Sud Harz										
04 Hossleben	1905	-	0.32	-	-	700	-	50	R & P	-
05 Sondershausen	-	-	-	-	-	-	-	50	R & P	-
06 Sollstedt	1905	-	-	-	-	-	-	50	R & P	-
07 Bleicherode	1902	-	-	-	-	-	-	50	R & P	-
08 Volkenrode	1909	-	-	-	-	-	-	50	R & P	-
09 Bischoffsrode	1915	-	0.510	-	-	-	-	50	R & P	-
Kali-und Steinsalzbetrieb Saale										
10 Teutschental	1907	-	-	-	-	-	-	50	R & P	-
Kalibetrieb Zielitz										
11 Zielitz	1973	-	0.9	5.3	17	800	18-25	50	R & P	-
RUSSIA										
Ural										
01 Berezniki Nos. 1-4	1931		5.2-5.3	12.3-13.1	21	300-500	-	-	Dome & pillar	-
02 Solikansk Nos. 1&2	1931	15900	1.4	3.5	14-15	200-500	-	-	Room & pillar	-
03 Novo Solikansk	1983		1.9-2.0	4.5-5.0	14-15	200-500	-	-	Room & pillar	-
BYELORUSSIA										
04 Soligorsk Nos. 1-4	1963 (No. 1) 1978 (No. 4)	2800	5.0-5.2	11.8-12.1	13.4-17.7	420-650	5.0	80-85 overall 43-45 70-75 longwall	R & P, longwall	16000 Surf + U/G
Ukraine										
05 Kalush - Stepwik Area	1923 (old)	2900	0.4	0.9	8-12	100-300	19-27	90.5	R & P Shrinkage stoping	-

3.2 ASSESSMENT OF POSSIBLE PROBLEMS IN REGIONAL MINE STABILITY WITH FUTURE MINING OF SASKATCHEWAN POTASH

SCIENTIFIC AUTHORITY: M. Gyenge

CONTRACTOR: Potash Corporation of Saskatchewan $89 879.

OBJECTIVE:

1. Identify long-term problems of regional mine stability based on projected production plans and adverse effects observed up to the present.

2. Document case histories from engineering data at mine sites, which would show the relationship between surface subsidence and parameters such as: mining advance, extraction ratio, depth of mining, geological type of overburden, height and size of mined-out areas, and elapsed time.

3. Estimate the anticipated surface subsidence based on projected production plans, by using a suitable analytical method.

4. Quantify the adverse effects on the safety of operations relative to anticipated surface subsidence.

5. Identify and evaluate options for economically viable mining layouts to reduce long-term adverse effects on regional mine stability.

6. Identify the effects of salt backfill in terms of local and regional mine stability, surface subsidence and improved exploitation of potash resources.

OBJECTIFS:

1. Identifier les problèmes de stabilité régionale à long terme en fonction de projections de la production et des effets négatifs déjà observés.

2. Constituer des dossiers à partir de données techniques recueillies dans des mines, pour faire ressortir la relation entre une subsidence de surface et des paramètres tels que la progression des travaux d'exploitation minière, le rapport d'extraction, la profondeur de la mine, le type géologique des morts-terrains, la hauteur et la taille des zones creusées, et le temps écoulé.

3. Prévoir la subsidence de la surface à partir de projections de la production, par une méthode analytique convenable.

4. Quantifier les dangers d'une éventuelle subsidence de la surface pour la sécurité des opérations.

5. Identifier et évaluer les possibilités d'aménagement minier économiquement viables pour réduire les effets négatifs à long terme sur la stabilité régionale des mines.

6. Identifier les effets de l'utilisation de sel pour le remblayage sur la stabilité minière locale et régionale, la subsidence de surface et la rentabilité des exploitations de potasse.

PARTICIPANTS:

The participants in the contract, on a joint venture basis, are:

(a) Earth Sciences Section, Engineering Department of PCS Mining; as Project Leader and Coordinator

(b) The four potash mines operated by PCS Mining:
PCS Mining, Allan Division (Allan)
PCS Mining, Cory Division (Cory)
PCS Mining, Lanigan Division (Lanigan)
PCS Mining, Rocanville Division (Rocanville)

(c) Central Canada Potash Division of Noranda Mines Limited (CCP)

(d) Noranda Research Centre, Pointe Claire, Québec, (CRN)

METHODOLOGY USED FOR DATA COLLECTION AND ANALYSIS:

The data collection and analysis were guided by a committee consisting of the Senior Scientist of Earth Sciences, PCS Mining, as Chairman, the Chief Mine Engineers of the five participating mines and the Project Coordinator/Analyst (from Earth Sciences, PCS Mining).

To determine the type, quantity and quality of available data, a series of questionnaires was sent to each of the five mines. The questionnaires focused on the following topics:

(a) Subsidence

(b) Earthquakes and water inflows

(c) Historical mine development.

The data extracted from the questionnaires, as well as from direct interviews, were compiled and analyzed to identify areas of required research and development in order to resolve the specific concerns.

RESULTS:

Contract work progressed well and the final draft report was submitted ahead of schedule. It has been reviewed and revised and the final report, due in January 1985, is being prepared.

The consensus of the various participants in the contract is that the project has been successful in achieving its objective within the limits imposed by the quantity and quality of the geotechnical data available.

The report under preparation identifies specific areas where research and development are required to ensure long-term regional mine stability for Saskatchewan potash operations.

The main areas of concern are summarized as follows:

1. Shaft stability in brine bearing strata is considered to be the primary concern. The central component of shaft stability is the shaft lining and its long-term strength and integrity. The report discusses potential causes of shaft instability and identifies the main areas of research required to ensure stability.

2. Mining-induced seismicity considers the probable causes of this phenomenon - mining pattern, extraction ratio, the rate of mining and subsidence.

3. Geological anomalies. The anomalous structures contributing to the instability - washouts, leached zones, collapsed structures and Winnipegosis mounds - are discussed.

4. Water inflow. The report examines the potential risk from formation waters and the threat from water bearing formations in the hanging wall: Dawson Bay, Souris River, Blairmore, etc. The basic design and layout of the potash mine, as a preventive factor in water inflow to the mine, is also addressed.

5. Brine injection wells. Under this topic, the installation of the wells is discussed in relation to the mining and environmental concerns regarding these wells. The report examines fundamental questions about these wells and their possible threat to the instability of the mine workings. In addition, the question of monitoring the injection wells is outlined, and the necessary steps required to appraise the database for injection pressures and chemical composition requirements are discussed.

6. Potash exploration wells. The drilling and abandonment practices in relation to these wells, the reliability of the cement plugs, and the isolation of a safety zone surrounding the projected exploration boreholes are the subjects of this discussion. The report also examines the possible hazard posed by abandoned wells.

The second part of the report deals with problems of subsidence due to potash mining and describes the use of an empirical subsidence prediction method applied to Saskatchewan potash mines. Subsidence data were collected from five producing potash mines in southern Saskatchewan.

Based on the results of the completed analysis the following conclusions are made:

1) The total subsidence of ground above Saskatchewan potash mines can be represented by two stages of development. At some time after the mining of an excavation an initial component of subsidence is experienced on surface, followed by a long-term constant rate of subsidence.

2) The magnitude of the initial effect of subsidence and the rate of long-term subsidence, are functions of the percentage of extraction and mining method.

3) Mines employing the same method of mining experience similar types of subsidence.

4) The "zone area" method of subsidence prediction has reproduced actual subsidence to a fair degree of accuracy for the limited number of available test cases.

5) Subsidence prediction by the zone area method requires that functions relating initial and long-term subsidence to the percentage of extraction are known.

In the subsidence analysis certain areas have not been considered. It is recommended that future studies should address the following:

- the effect of room/pillar height
- the effect of sequencing mining operations
- the effect of different rock types in the mining zone and overburden

- the location and effect of discontinuities in the mining zone and overburden
- the effect of earthquakes.

3.3 CREEP CELL EVALUATION AND LABORATORY TESTING OF LARGE EVAPORITE SAMPLES

SCIENTIFIC AUTHORITY: L.B. Geller

CONTRACTOR: Saskatchewan Research Council (Dr. R.G. Arnold) $39 938.50

SUB-CONTRACTOR: University of Saskatchewan Geological Engineering Dept. (Dr. Malcolm Reeves)

WORKSCOPE:

On behalf of the Canada Centre for Mineral and Energy Technology (CANMET) to test, evaluate and bring into operation, one of the existing creep pressure vessels at SRC, Saskatoon, for testing triaxial creep properties of salt and potash samples.

Mr. Geller gave a brief introduction by reviewing the progress reported at the February 29, 1984 progress review meeting (CANMET report MRP/MRL 84-24), and by summarizing the contents of Prof. Reeves' draft final contract report.

OBJECTIFS:

Pour le compte du Centre canadien de la technologie des minéraux et de l'énergie (CANMET), tester, évaluer et mettre en service un des réservoirs sous pression de fluage existant au SRC, à Saskatoon, pour analyser les propriétés de fluage triaxial de différents échantillons de sel et de potasse.

Dans une brève introduction, M. Geller a rappelé les progrès signalés lors de la réunion du 29 février 1984 (rapport MRP-MRL 84-24 du CANMET) et a résumé le contenu du projet de rapport final du professeur Reeves.

RESULTS:

In his address, Prof. Reeves thanked PCS and Cominco Ltd. for their generous cooperation by providing specially drilled large size (20-cm diam) samples at no cost. The design details of the test facility were briefly reviewed, such as the hydraulic loading systems and their control by solenoids, strain gauges and computer. Prof. Reeves then stated that the project objective, of making operational one of the new creep vessels for testing evaporites, had been achieved. Satisfactory creep tests can now be performed, even if by rather work-intensive and somewhat time-consuming means (particularly during the preparatory stage and also because of a lack of suitable computer controls). As an example, he thought considerable improvements could be achieved at relatively modest additional costs if the sensitivities of the pressure transducers were changed; if linear potentiometers were available; and if computer software and sensor development could be financed. Moreover, with temperature controls and a heater for the hydraulic oil in the radial pressure circuit, the Large Sample Triaxial Test Facility (LSTTF) could determine the creep/flow characteristics of evaporites over a wide range of temperatures.

The value of the LSTTF as a research tool for resource-based industries was then reviewed. Its ability to determine the material properties of very large (20-cm diam and 40-cm long) test pieces was explained, such as obtaining shear and triaxial strengths at a maximum of 125 millistrains/s and establishing a range of creep rates. Moreover, consolidation rates and permeabilities could also be obtained for tailings if an additional pore pressure tap was installed.

Prof. Reeves next elaborated on the need to know the above-mentioned rock property values, and in what way industry would benefit from this knowledge. In particular, he pointed to the importance of these data in the case of: mine design in coarsely crystalline evaporites, where crystal sizes are in the order of 10 cm; strength testing of mill-tailings; testing the consolidation of tailings; and determination of creep in unconsolidated tar sands and oil-shales. The LSTT facility may also be used to measure consolidation properties and permeability of fractured tills, as well as to study the recharge mechanisms for tills and fractured rock masses.

Overhead transparencies were used to illustrate the essential design features of the LSTTF. Serious leaks in the hydraulic system were detected. These have now been reduced to the point where radial and axial pressures can be maintained at constant levels. Piston-sticking problems were encountered for a range of velocities. After some modification, the piston can now be moved easily and smoothly at pressures up to 80 kPa. Figure 3-1 illustrates the consistency of results obtained with the aluminum test cylinders at the LSTTF laboratory and the Geological Engineering Laboratory at the University of Saskatchewan (GELUS). The same consistency of results was demonstrated in the case of potash samples. Figure 3-2 shows the stress/strain results when loading to failure at 0.12 MPa/min. This figure also illustrates how consistently the linear potentiometers measured strains. Figure 3-3 illustrates the results of a creep test of 200 h duration, including the little steps caused by overnight manual controls which were the only ones available at the time. The consistency of results obtained by axial potentiometers and axial strain gauges was mentioned. A creep test had been underway for 52 days and was still in progress at the time of the seminar.

Figure 3-4 illustrates that setting the deviator stress at more than 6 MPa was too much since, in this case, e.g. 26.4 MPa with confining pressure equal to 10 MPa, the sample failed in less than seven hours after it had barrelled excessively. The results obtained by axial potentiometers and strain gauges did not match. The diameter strain gauges failed prematurely, which was quite understandable since these had to record some 400% of their design strain level. On the whole, gauges and potentiometers performed extremely well up to the limit of their normal ranges, and even beyond in some instances.

A brief question and answer period followed on the precise meanings of sample failure and deviator stress. This was followed by comments from the floor to the effect that the LSTT Facility appeared to be an excellent one, possibly the best of its kind in the world. It could, therefore, provide a worldwide service, and should consequently be given as much help and support as possible.

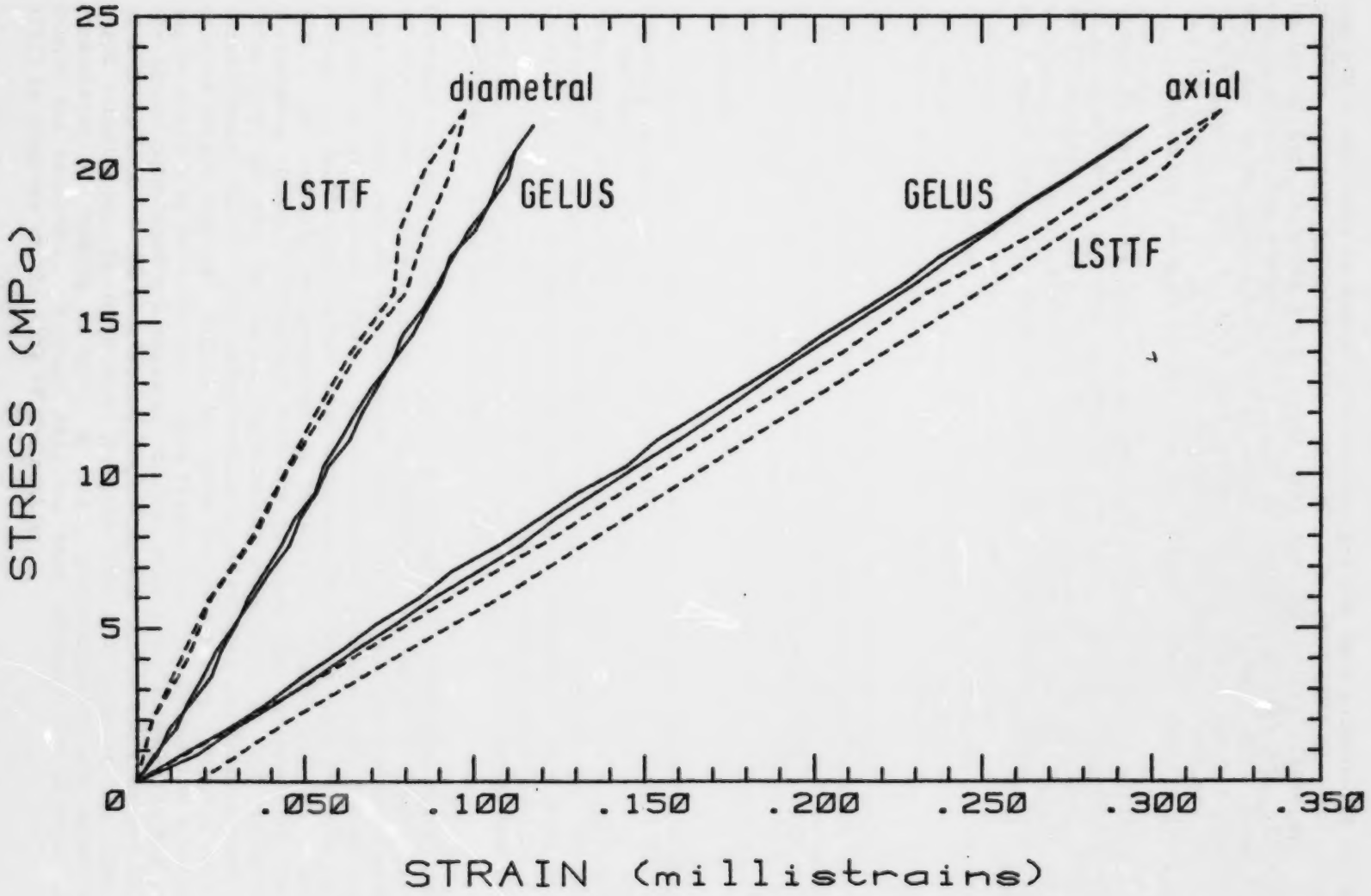

Fig. 3-1 - Calibration test #1 and #2: stress-strain load-unload cycle curves for aluminum cylinder

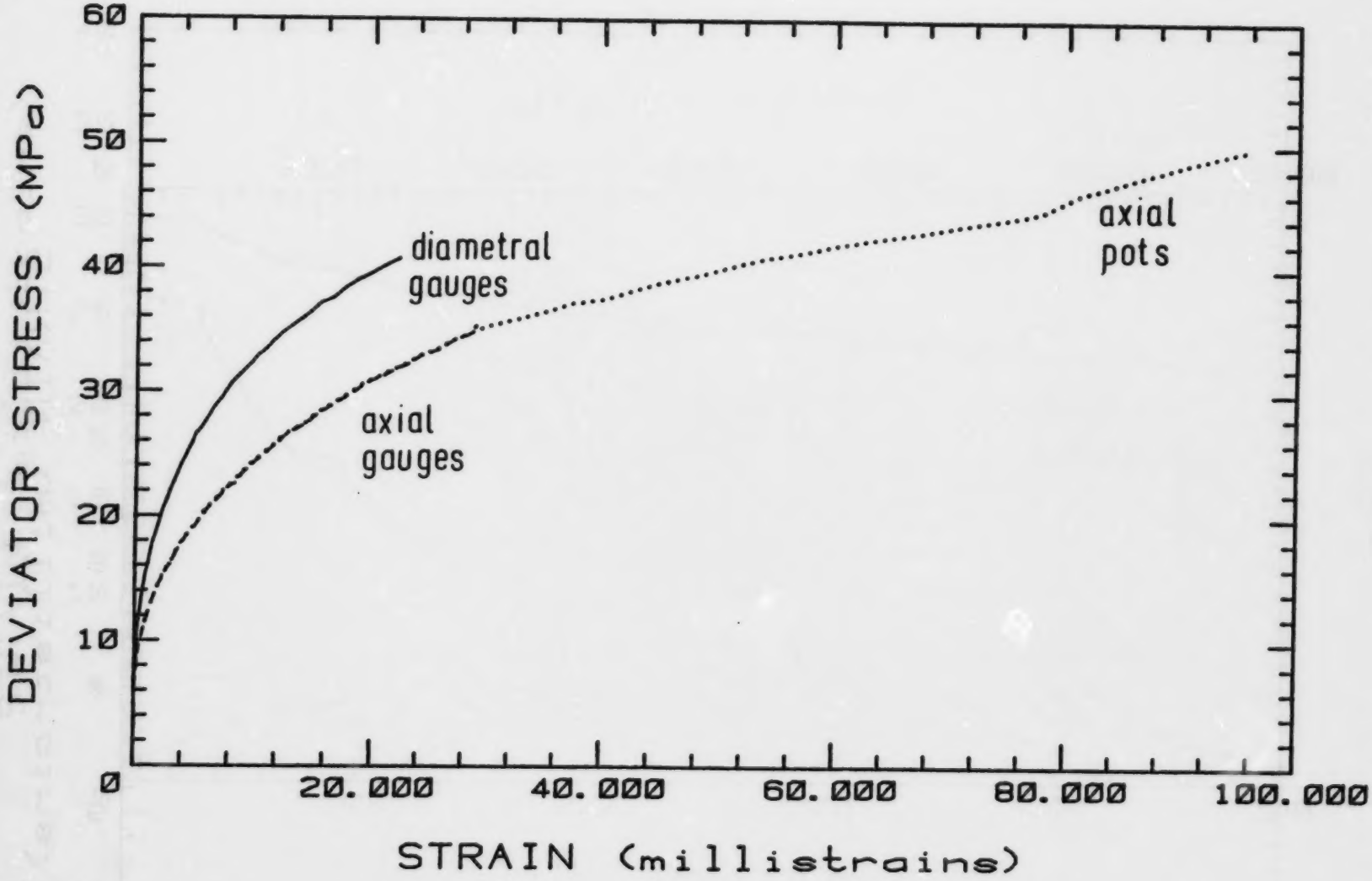

Fig. 3-2 - Strain-time curves for triaxial load test #7.6 on potash core C1

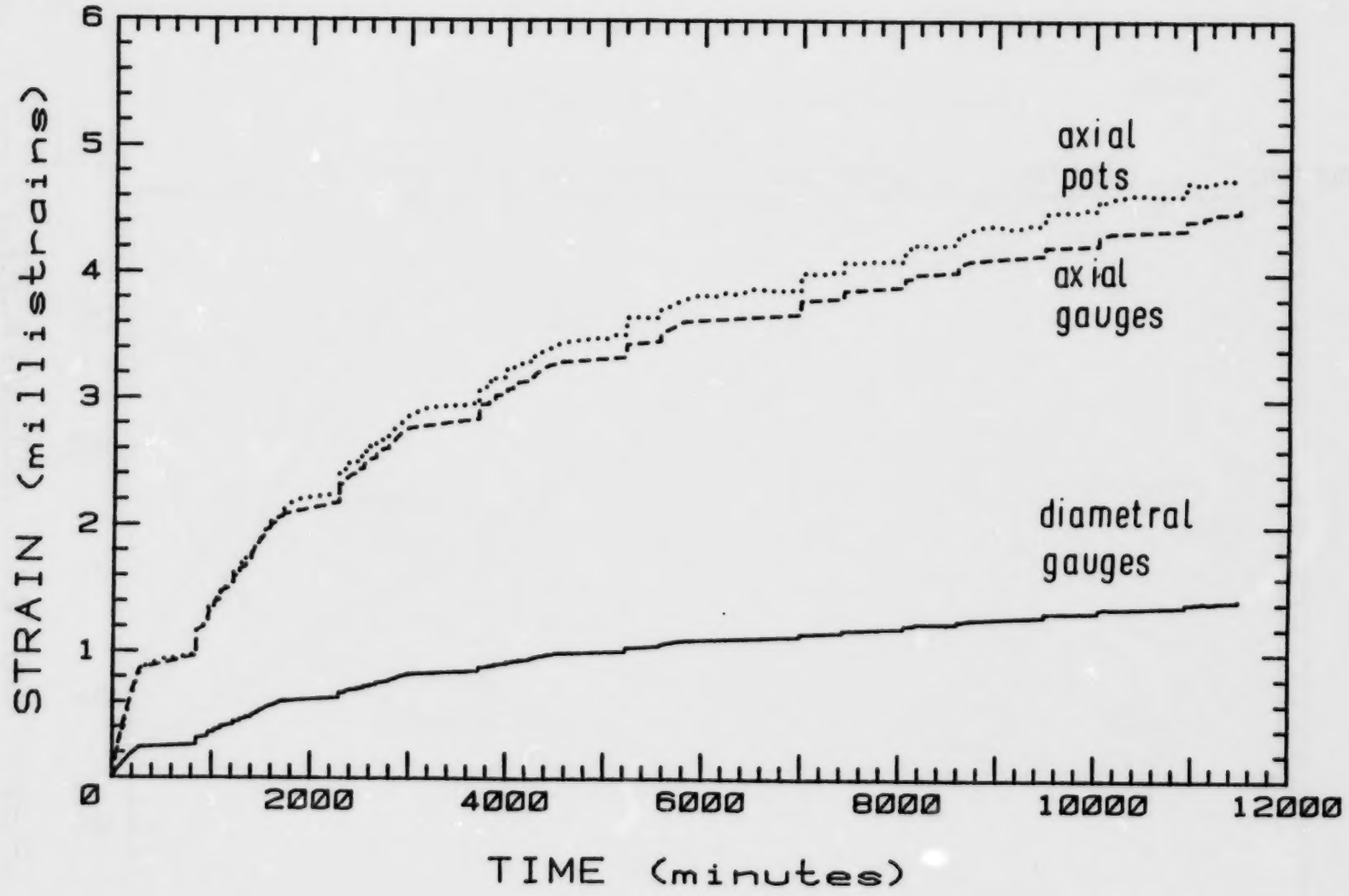

Fig. 3-3 - Strain-time curves for triaxial creep test #7.5 on potash core C1

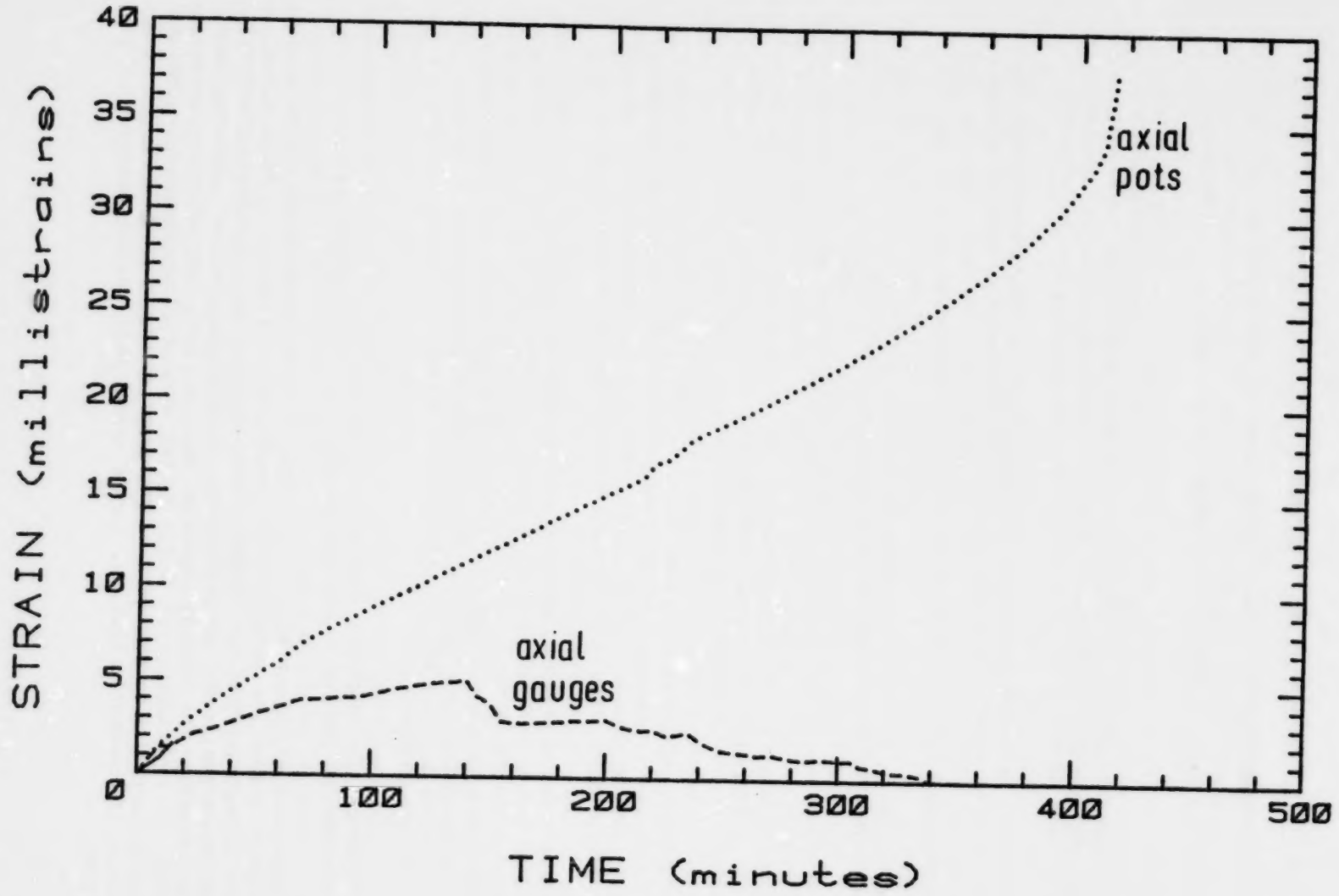

Fig. 3-4 - Strain-time curves for triaxial creep test #9.1 on potash core C3

3.4 NUMERICAL MODELLING PACKAGE TO DESIGN UNDERGROUND OPENINGS IN POTASH

SCIENTIFIC AUTHORITY: Y.S. Yu

CONTRACTOR: RE/SPEC Ltd. Calgary, Alberta $47 579.

WORKSCOPE:

1. Compile existing constitutive relationships and define the most appropriate ones which would simulate the transient behaviour of potash and/or rock salt material around underground mine openings.

2. Develop a two-dimensional or, if appropriate, a three-dimensional numerical model, which would use the above-identified constitutive relationships, and which could be used for modelling the rock behaviour around underground openings in deep potash and/or salt mines.

3. Carry out a review of failure criteria appropriate for evaporites and incorporate the most appropriate choice into the model.

4. The numerical model (finite element, boundary element or combination) should be written in accordance with the standard of FORTRAN ASCII 77 for portability (machine independence). The codes should be capable of modelling large mine structures economically and efficiently, and should be capable of modelling mining sequences, i.e., excavating and/or backfilling. Pre- and post-processor capability needs to be available for quick processing of input data and output results. In addition, the numerical model needs to be able to represent a four-layer formation sequence but need not be able to represent anisotropy. The immediate roof should be considered to extend one or two diameters away from the mine opening.

5. Prepare a user's manual. Run a test program on a typical mined-out room, which has been backfilled using waste salt from potash mining. Consideration should be given to the effectiveness of backfill on stabilizing mined out areas as a consequence of the increased internal rock pressures due to convergence of surrounding strata. Verification of the program code should be carried out by experimental evaluation (physical model) or by field measurement data.

6. Recommend the necessary R & D work in relation to additional development of numerical modelling for potash/salt mine planning and operation.

The objective of this project is to develop a numerical model which will be capable of simulating visco-elastic behaviour of potash/rock salt materials around underground openings in deep potash mines. The capability of modelling mining sequences, i.e., excavation and backfilling, and of treating anisotropic behaviour for layered deposits, will be taken into account. Extensive testing and verification of the computer code will be conducted; pre- and post-processor will be incorporated for easy input-data preparation and interpretation of computer output. A user's manual with testing examples will be prepared.

OBJECTIFS:

1. Compiler les relations de base existantes et définir les relations les plus appropriées qui simuleraient le comportement transitoire de la potasse ou du sel gemme autour des ouvertures souterraines des mines.

2. Mettre au point un modèle numérique à deux dimensions ou, si nécessaire, à trois dimensions, qui utiliserait les relations de base susmentionnées et qui pourrait être utilisé pour la modélisation du comportement des roches autour des ouvertures souterraines dans les mines profondes de potasse ou de sel ou les deux.

3. Examiner des critères de défauts pour les évaporites et incorporer au modèle un choix des critères les plus appropriés.

4. Le modèle numérique (éléments finis, éléments limites ou combinaison des deux) devrait être rédigé en FORTRAN ASCII 77 pour être transférable (indépendant de la machine). Les codes devraient permettre de modéliser économiquement et efficacement les grands ouvrages miniers, ainsi que les séquences minières, c'est-à-dire l'excavation et le remblayage, ou les deux. Il faudrait prévoir d'un préprocesseur et un postprocesseur de façon à traiter rapidement les entrées et les sorties. De plus, le modèle numérique doit être capable de représenter une série de quatre couches d'une formation mais non l'anisotropie. Le plafond immédiat devrait déborder d'un à deux diamètres de l'ouverture de la mine.

5. Préparer un manuel de l'utilisateur. Exécuter un programme de vérification sur une chambre type remblayée avec du sel résiduel provenant d'une mine de potasse. Tenir compte de la capacité du remblai à stabiliser les aires excavées en équilibrant les pressions internes accrues exercées par la roche à cause de la convergence des strates qui l'entourent. Vérifier le code du programme expérimentalement (modèle physique) ou à l'aide de mesures prises sur le terrain.

6. Recommander les travaux nécessaires de R-D pour approfondir la modélisation numérique aux fins de la planification et de l'exploitation des mines de potasse et de sel.

L'objectif de ce projet est de mettre au point un modèle numérique pour simuler le comportement visco-élastique de la potasse et du sel gemme autour des ouvertures souterraines dans les mines de potasse profondes. Il faudra tenir compte des possibilités de modélisation des étapes minières, notamment l'excavation et le remblayage et de la capacité de traiter le comportement anisotropique des dépôts en couche. Les codes informatisés seront soumis à des vérifications et des essais poussés; un préprocesseur et un postprocesseur seront incorporés pour faciliter la préparation des entrées et l'interprétation des sorties de l'ordinateur. Un manuel de l'utilisateur, illustré d'exemples d'essais, sera préparé.

RESULTS:

The project was about 90% complete as of November 1984. A one month delay for the final review and the acceptance of the contract report could be expected. This delay was mainly due to the process of debugging the software and would postpone the completion date until January 1985.

A number of problems had been experienced during the debugging stage; e.g., implementation of the capability for simulating mining sequences, such as excavation and backfilling; however, these problems had been rectified as reported by RE/SPEC recently.

The end product of this contract will be the software package - GEOROC. A final report includes a brief description of methodology used for modelling the transient behaviour of potash/rock salt materials, a user's manual for GEOROC, pre-processor (GEOMESH) and post-processor (ALGEBRA, TPLOT and SPLOT) routines. In addition, a test example of a typical form-and-pillar layout for a potash mine, with rooms backfilled with waste materials, will be illustrated.

Program Capabilities:

The capabilities of GEOROC are outlined as follows:

a) Geometry:
Limited to two-dimensional (plane strain and plane stress) and axisymmetric geometries.

b) Material models:
Isotropic elastic and/or viscoelastic material properties can be modelled. Each element in the mesh may have its material property specified. Three constitutive laws describing the creep behaviour of the material are incorporated in GEOROC. The empirical power law is suitable for simulating the initial, transient portion of creep. The Norton law is suitable for modelling steady-state creep and has received relatively widespread use in modelling the behaviour of salt mines and solution caverns in salt. The exponential-time law is also incorporated and models both transient and steady-state creep.

c) Mining sequences:
It is capable of simulating various mining sequences, i.e., excavation and/or backfilling operations.

d) Loading:
Pressures may be applied to the interior walls of excavations for simulation of support systems, storage of fluids or backfill. Initial state of stress based on the weight of overburden and lateral earth pressure coefficient, or based on body forces, can be considered.

e) Boundary conditions:
Kinematic (displacement) constraints, external surface loading, and skewed boundary orientation relative to the global axes are incorporated.

f) Factor of safety:
Two different formulations for a factor of safety are incorporated. The first, the well-known Mohr/Coulomb criterion,lis suitable for assessing brittle failure in elastic rocks. The second is based on total creep strain and is suitable for assessing potential failure in visco-elastic materials.

g) Alteration of mechanical properties:
Mechanical properties of selected elements may be altered during the process of analysis. This feature is intended for modelling backfill behaviour.

Pre-processor:

GEOMESH, a mesh generator for the finite element GEOROC, is based on the concept of mapping using isoparametric shape functions, and it generates part of the input data (nodal coordinates and element parameters, boundary constraints, etc.) for the program GEOROC. This input combined with additional information forms an input file which will be acceptable to GEOROC. It is fairly flexible and allows a variety of complex meshes to be generated with relative ease.

Post-processor:

A package of three programs (ALGEBRA, TPLOT and SPLOT) is presented and can be used as a post-processor for interpretation and analysis of the massive output produced by GEOROC.

- TPLOT generates X versus time plots, where X is an appropriate output variable, such as stress or displacement, selected by the user.
- SPLOT generates X versus distance plot.
- ALGEBRA allows the user to create functions for analyzing the output data from GEOROC (for example, to calculate a factor of safety or effective stresses, etc.) which in turn can be plotted by TPLOT and SPLOT.

None of these options have been tested at the Mining Research Laboratories.

Program verification:

Cantilever beam:

To verify that GEOROC provides correct predictions of mechanical behaviour at the fundamental level, a simple cantilever beam was analyzed. Agreement between the analytical solution and the finite element approximation was within ±0.4% and therefore can be considered very good.

Thick-walled cylinder:

A thick-walled cylinder under axisymmetric internal pressure loading was used for further verification of GEOROC. The cylinder consisted of visco-elastic material and was governed by a power law. An analytical solution was avail-

able for comparison. The stresses and displacements predicted by GEOROC were in good agreement with the analytical solution.

Potash Mine Simulation:

A hypothetical five-room panel, relating to the Cominco mine, was prepared and analyzed. This model incorporated the Dawson Bay formation as well as evaporites. Rooms were excavated sequentially, creating two situations for investigation and examination. In the first case rooms were mined sequentially, without backfill, and in the second case, rooms were mined and backfilled at a later date.

The finite element model for the Cominco mine is shown in Fig. 4-1 (a) and Fig. 4-1 (b). The material properties used in the simulation are shown in Table 4-1 and expressed as an empirical powerlaw to describe the transient creep. The law is expressed as:

$$e = As^m t^n$$

where e = a scalar measure of transient strain
s = axial stress difference
t = time since loading
A, m, n = experimentally determined constants.

Some of the preliminary results from this simulation are illustrated in Fig. 4-2 and 4-3. The general trend of the room closure as a function of time seems to be realistic; unfortunately, there were no field measurements available for comparison at this time.

Distribution of the GEOROC modelling package:

During the debriefing session, a number of people indicated an interest in learning how GEOROC would be made available to the potash mining community as well as to the Canadian mining industry. A solution will be proposed in consultation with RE/SPEC.

CONCLUSIONS/RECOMMENDATIONS:

GEOROC is a useful tool which has a wide range of potential applications in potash rock mechanics and mine design. However, one must realize that the usefulness of this analytical tool is directly related to the quality of the input data and the empirical constitutive laws incorporated in the program. At present, very little is known about the mechanical properties and creep behaviour of salt/potash materials. Therefore, verification and calibration of material models are required. Integrated studies of detailed laboratory investigation of salt/potash properties, and well-planned underground monitoring and modelling programs, are required. In addition, a benchmark comparison with other computer codes would be very useful.

Table 4-1 - Rock properties used in the potash mine simulation

	Dawson Bay formation	Evaporite	Backfill
Young's modulus (GPA)	25	20	0.875
Poisson's ratio	0.32	0.33	0.4
Density (kg/m^3)	2500	2180	1920
Loading coefficient (A)	-	2.605×10^{-11}	-
Power on stress (m)	-	7.5	-
Power on time (n)	-	0.39	-

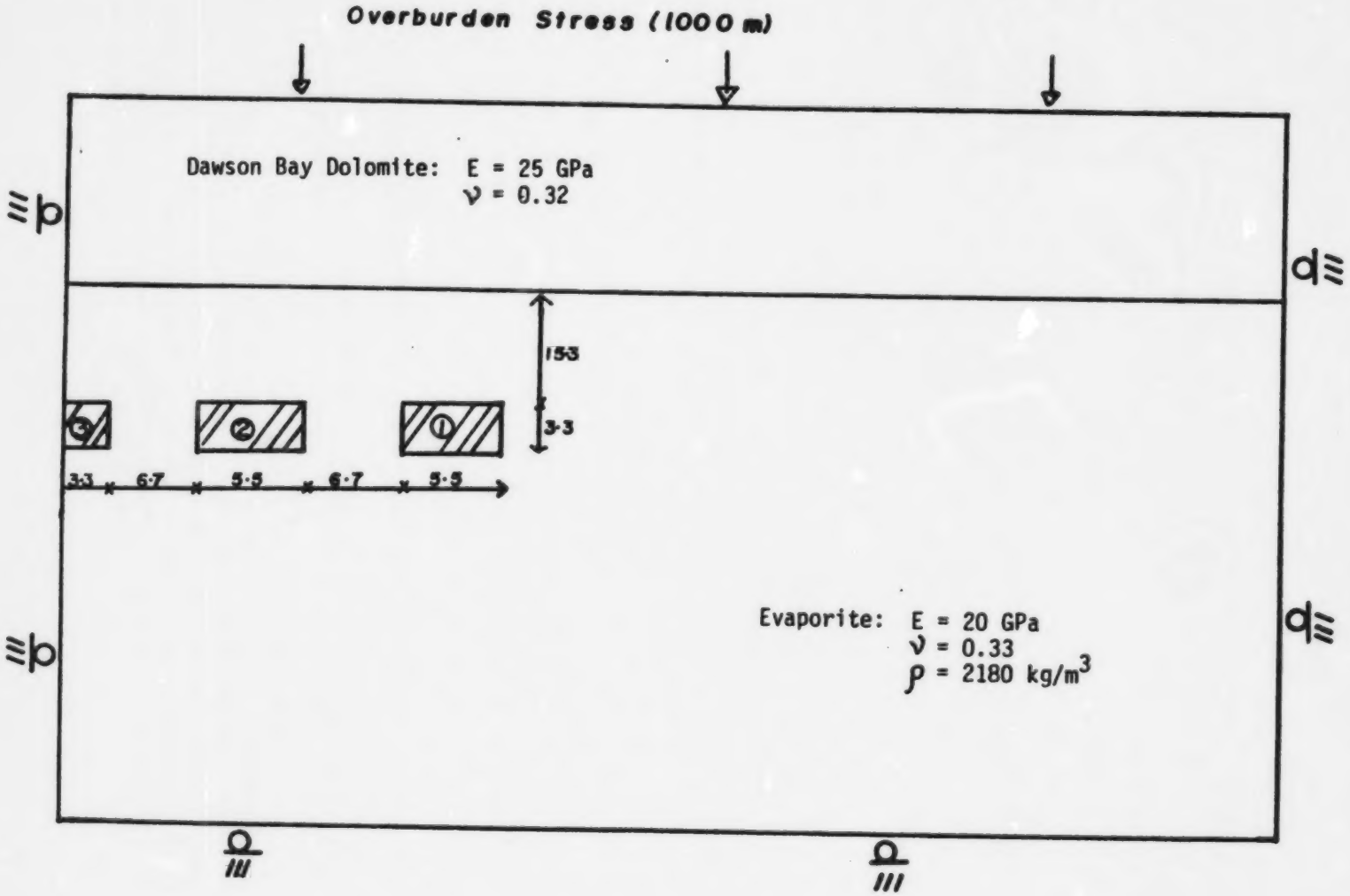

Fig. 4-1(a) - Potash mining simulation, based on Cominco Mine layout. (All dimensions in metres.)

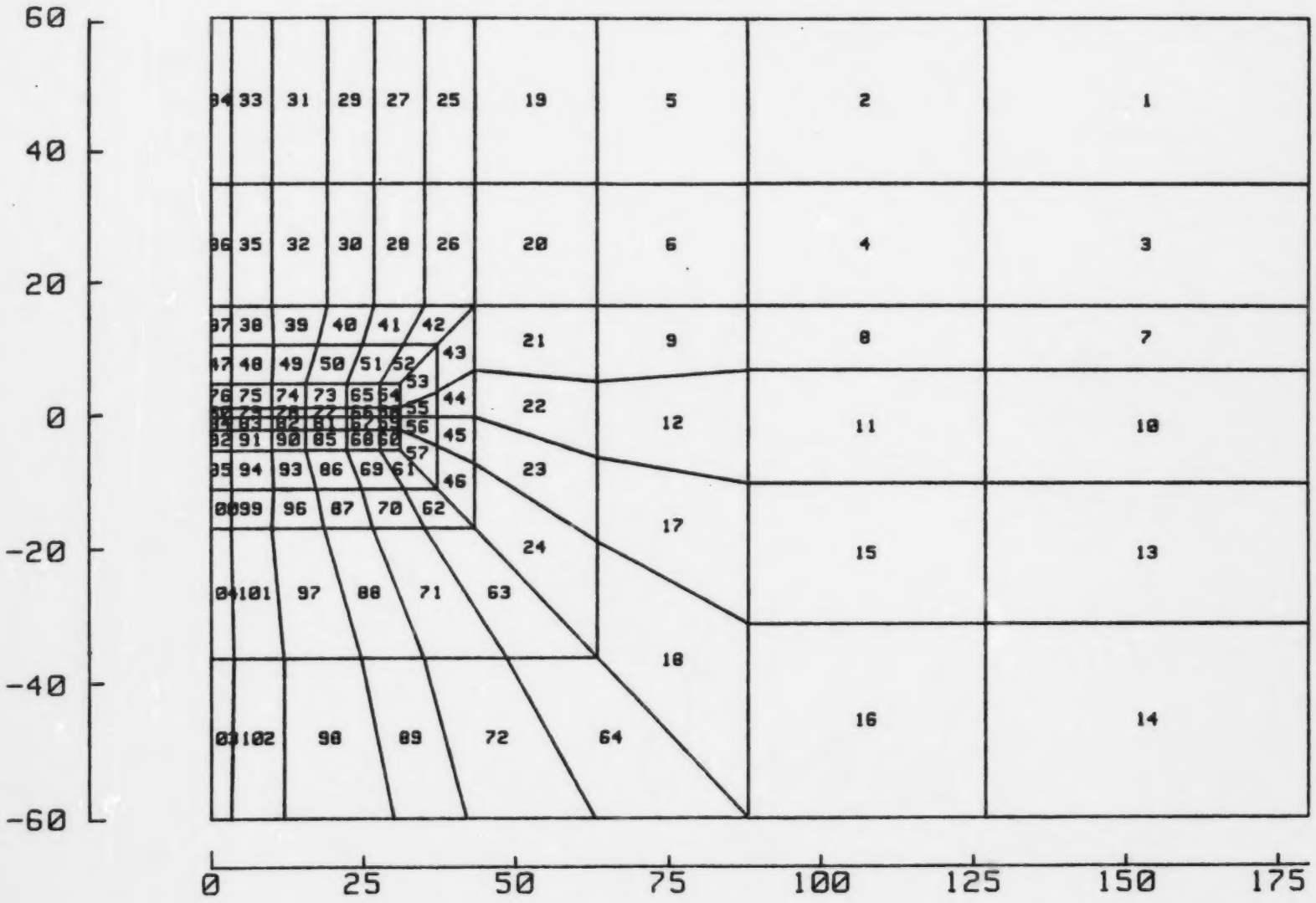

Fig. 4-1(b) - Finite element mesh for potash problem.

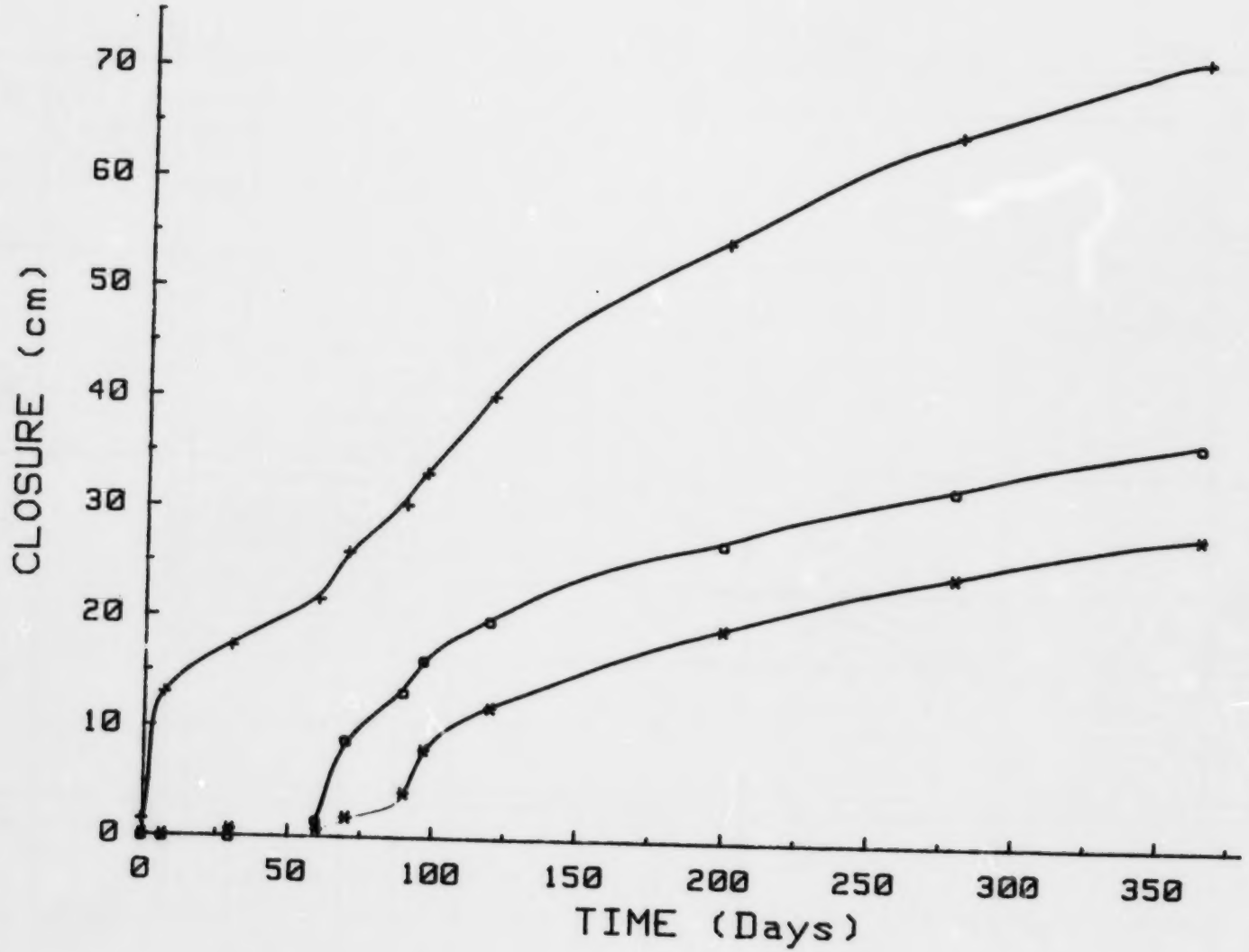

Fig. 4-2 - Vertical creep closure of rooms 1(+), 2(0) and 3(*) as a function of time (no backfill).

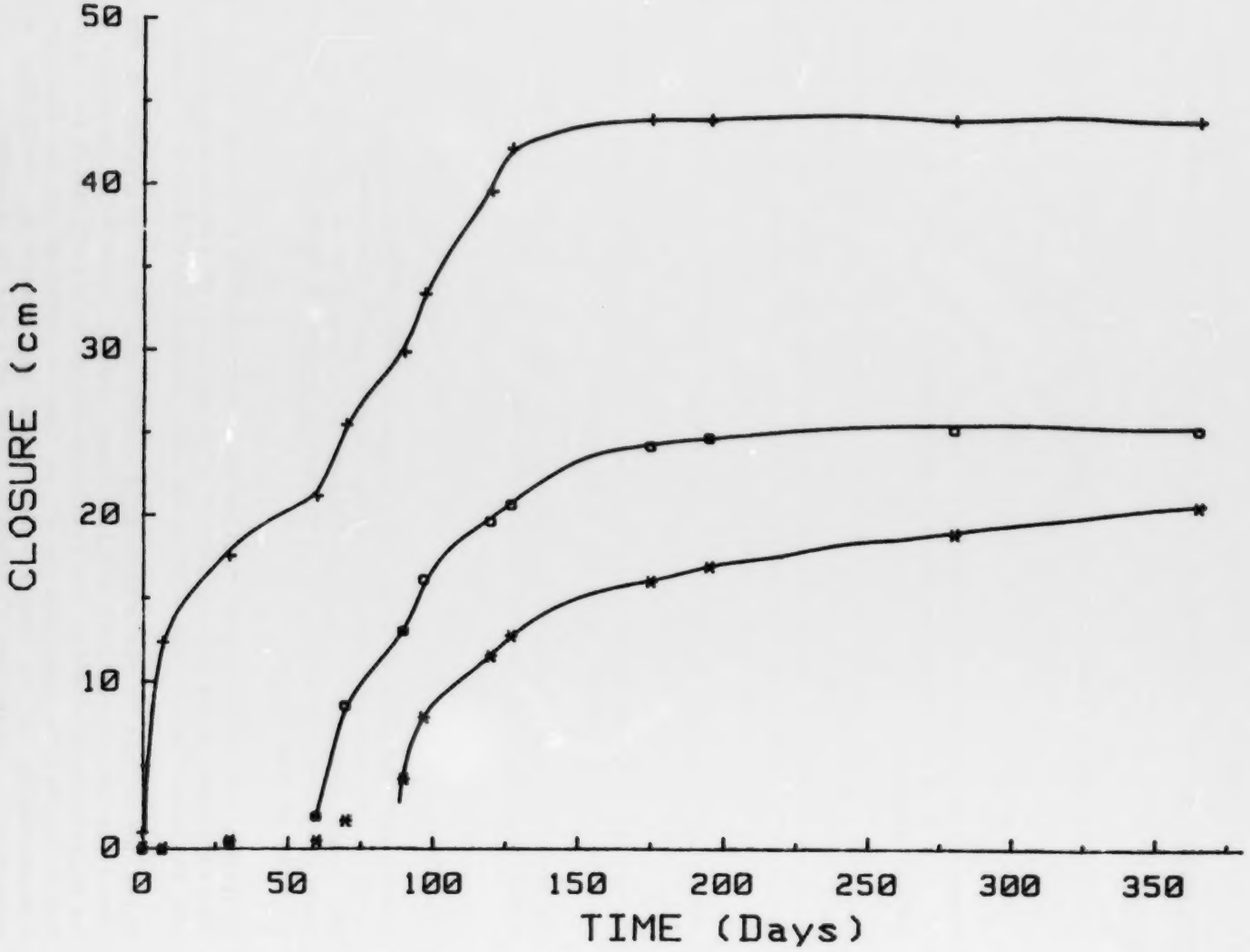

Fig. 4-3 - Vertical creep closure of rooms 1(+), 2(0) and 3(*) as a function of time. Room 1 was backfilled at 130 days and room 2 at 180 days after excavation.

3.5 DETERMINATION OF ENGINEERING PROPERTIES OF WASTE SALT FOR BACKFILLING UNDERGROUND POTASH MINES

SCIENTIFIC AUTHORITY: M. Bétournay

CONTRACTOR: RE/SPEC $25 250.

WORKSCOPE:

1. Determine the suitability of different types of waste salt, obtained during potash mining or processing, for backfill. Important properties relate to grain size distribution, mineral composition, and moisture content with respect to mode of placement.

2. Prepare representative cylindrical samples with a height-to-width ratio of 2:1 from a suitable backfill material, e.g., NaCl mill wastes at 10-15% moisture.

3. Carry out compression tests to determine the resistance a backfill waste salt offers to closure and subsidence. This should provide load/bulk density relations in a rigidly confined compression test and rate of compression per load increment. For all compression tests determine porosity before and after testing.

4. Determine internal angle of friction and cohesion to calculate lateral fill pressure on walls of excavations.

5. Determine changes of percolation rate or permeability with changes of density for different types of waste salt.

6. Determine porosity, water content, void ratio, strength and deformation properties for a suitable backfill material at maximum density.

OBJECTIFS:

1. Déterminer les possibilités d'utilisation de différents types de sels résiduels, obtenus au cours de l'exploitation ou du traitement de la potasse, comme remblai. La granulométrie, la composition minéralogique et la teneur en humidité sont d'importantes propriétés à déterminer en fonction du mode de remblayage.

2. Préparer des échantillons cylindriques représentatifs, ayant un rapport hauteur/diamètre de 2:1, à partir d'un matériau de remblayage approprié, par exemple, des déchets d'usine de NaCl titrant de 10 à 15 % d'humidité.

3. Faire des essais de résistance à la compression pour déterminer la résistance que le sel résiduel utilisé comme remblai offre à la fermeture et à la subsidence et établir des relations charge/poids volumétrique, dans un essai de stricte compression, et un taux de compression en fonction de l'augmentation de la charge. Pour tous les essais de résistance à la compression, déterminer la porosité avant et après les essais.

4. Déterminer l'angle interne de frottement et la cohésion pour calculer la pression latérale exercée par le remblai sur les parois des excavations.

5. Déterminer les changements dans le taux de percolation ou dans la perméabilité en fonction des changements de densité de différents types de sels résiduels.

6. Déterminer la porosité, la teneur en eau, et, les propriétés de résistance et de déformation recherchées dans un matériau de remblayage de densité maximale.

RESULTS:

Mr. R. Beddoes summarized the testing program and the results obtained. The testing program consisted of:

1. Material characterization

2. Quasi-static consolidation tests

3. Exploratory creep consolidation tests

4. Post-consolidation characterization by
   i. strength tests
   ii. moisture/density tests
   iii. microscopic study.

Crushed salt tailings, consisting of 95-98% halite and 2-5% sylvite, were used in quasi-static tests, under loads of 7, 14, 25 and 35 MPa. Creep tests were carried out with a load of 25 MPa for 7, 14 and 25 days. Moisture contents of 2, 5 and 10% were used in the consolidation tests, while moisture contents of 5% were used in the creep tests. Uniaxial or triaxial tests were used to determine the strength of consolidated samples or samples which had been subjected to creep.

The results were as follows:

1. Under quasi-static consolidation tests, the final density of specimen is not influenced by moisture content (for higher loads). No unconfined strength is produced.

2. In creep tests, there is a rapid gain of strength and rapid loss of moisture. A void ratio of 12% exists after 28 days of loading.

3. Strength tests have shown that there is no significant development of strength, unless samples have experienced creep. The Mohr-Coulomb criterion applies only at low stresses. After creeping, particle fusion allows strength to approach that of solid salt.

DISCUSSION:

Mr. D. Mraz of Mraz Project Consultants inquired about the criterion for failure. The speaker answered that it was taken arbitrarily at the 5% strain point, at which the load deformation curve becomes parallel to the deformation axis. Dr. P. Kaiser of the University of Alberta asked how the compressive stress was calculated, and Mr. Beddoes answered that it was based on the original sample area. Mr. Mraz commented that the presented downturn of the Mohr's envelope at high confining pressures represents an implosion of the sample which does not reflect field conditions. Dr. M. Dusseault of the University of Waterloo stated that salt does not behave elastically and thus the Mohr criterion is inappropriate. Dr. M. Reeves of the University of Saskatchewan stated that strength is loading rate dependent in creep tests.

3.6 DUST MEASURING TECHNIQUES AND DUST LEVELS IN POTASH MINES

SCIENTIFIC AUTHORITY: G. Knight

CONTRACTOR: The Cambrian Engineering Group Ltd. $27 000.

WORKSCOPE:

1. Determine the most appropriate method for measuring dust levels in potash mines.

2. Survey dust levels in at least four potash mines in relation to cutting techniques, and determine possible improvements.

3. Describe for the above mines, the detailed ventilation arrangements at the face and the active panel during mining, and determine possible improvements.

4. Estimate operator exposure to dust loads and effects on operator safety, efficiency and cutting machine performance.

5. Suggest future research needs in the subject area.

OBJECTIFS:

1. Définir la méthode la plus appropriée pour mesurer la concentration en poussière dans les mines de potasse.

2. Relever les concentrations de poussière dans au moins quatre mines de potasse en fonction des techniques de taille utilisées et suggérer des améliorations possibles.

3. Décrire en détail, pour les mines susmentionnées, le système de ventilation utilisé sur le front de taille et dans la chambre en cours d'exploitation et suggérer les améliorations possibles.

4. Estimer le niveau d'exposition des mineurs aux poussières et ses effets sur la sécurité et l'efficacité des opérations et sur le rendement des haveuses.

5. Identifier les besoins futurs de recherche dans le domaine.

RESULTS:

Dust Sampling

Dr. Yoshida, Saskatchewan Research Council, had earlier reviewed the relation between dust particle sizes and the affected respiratory system parts, and the effectiveness of sampling instruments in relation to the smallest possible particle size detection.

Twelve critical factors for the sampling of salt dust were presented:

1. wide range of concentrations
2. water solubility
3. hygroscopicity
4. electro-conductivity
5. high refractive index
6. concept of respirable dust
7. geometry of inlet orifice
8. wind speed and inlet orientation
9. personal or area sampling
10. electrolyte or not
11. geometry and size of equipment
12. electrical safety.

Samples were taken at various sites to provide an indication of operator exposure. Typical sites included miner operator's station, bridge conveyor and transfer points in the conveyor system. In some cases, the bridge conveyor system incorporated a breaker system but this did not appear to materially affect the results.

The dust samplers tested may be divided into two types:

a) Samplers for inhalable dust:
   - open face cassettes with glass fiber filter in face down position;
   - closed face cassettes with membrane filter (method normally used in Saskatchewan);
   - ORB multi-directional samplers with glass fibre filter.

b) Samplers for respirable dust:
   - MRE gravimetric samplers with horizontal elutriator (glass fibre filter);
   - nylon cyclones with membrane filters;
   - metallic cyclones (Cassella) with glass fibre filter.

The results obtained from the individual samplers were compared with the mean for each class. The results were shown in tables and charts. Mean concentrations of inhalable dust ranged from 30 to 550 mg/m^3 at the mine site, 140 to 300 mg/m^3 at the bridge conveyor and 60 to 170 mg/m^3 at transfer points.

Data evaluation is still underway; however, it appears that the samplers showing the highest reproducibility of results were the open face cassettes under type (a) dust samplers, and the MRE elutriator under the type (b) dust samplers (Fig. 5-1).

Results obtained for other samplers were documented. The coarseness index, which is an inverse of respirable dust fraction, was found to be positively related to the inhalable dust concentration. The collection characteristics of samplers are known to be affected by the geometry and dimensions of the sampling inlet and by the particle size distribution. Further investigations are required to accumulate sufficient realistic data to produce recommendations on suitable samplers for potash production environment monitoring.

VENTILATION:

Ventilation in potash mines is generally adequate for the control of diesel emissions and to provide cooling for equipment. Dust levels are acceptable from the aspects of visibility and comfort at most locations, with the exception of the mining machine locations and conveyor transfer points. At some conveyor transfer points, the dust levels are high enough to pose a safety hazard due to reduced visibility. The main problem observed was the dust level at the mining machines, particularly at the machine operator's position. Observations were made at operations where the air was supplied from the front of the machine (on second pass) and from behind the machine. Since dust is generated at both the cutting face and the rear transfer point, the operator is exposed to dust in both systems.

CUTTING PARAMETERS:

Each of the different operations observed employed different combinations of tooling and cutting practice. Within the constraints of this project no correlation was found between these factors and the amount of dust generated. It was observed, however, that the operations achieving the highest rates of production had the highest sustained dust levels.

CONCLUSIONS:

The results obtained are still being analyzed but the following preliminary conclusions may be made.

Of the samplers for inhalable dust, the open face, downward facing cassette appears to give the most consistent results. Among the samplers for respirable dust, the MRE unit is fairly bulky. The metallics cyclone is much lighter and has a linear characteristic but requires a correction factor.

Operations in most mines produce dust levels that appear high for operator safety and comfort. Further investigations are required to develop suitable means of monitoring and reducing dust levels.

It was not possible to make a correlation between mining methods and dust production. Further investigation should include total sampling, including belt sampling, and bench tests, including individual cutter tests.

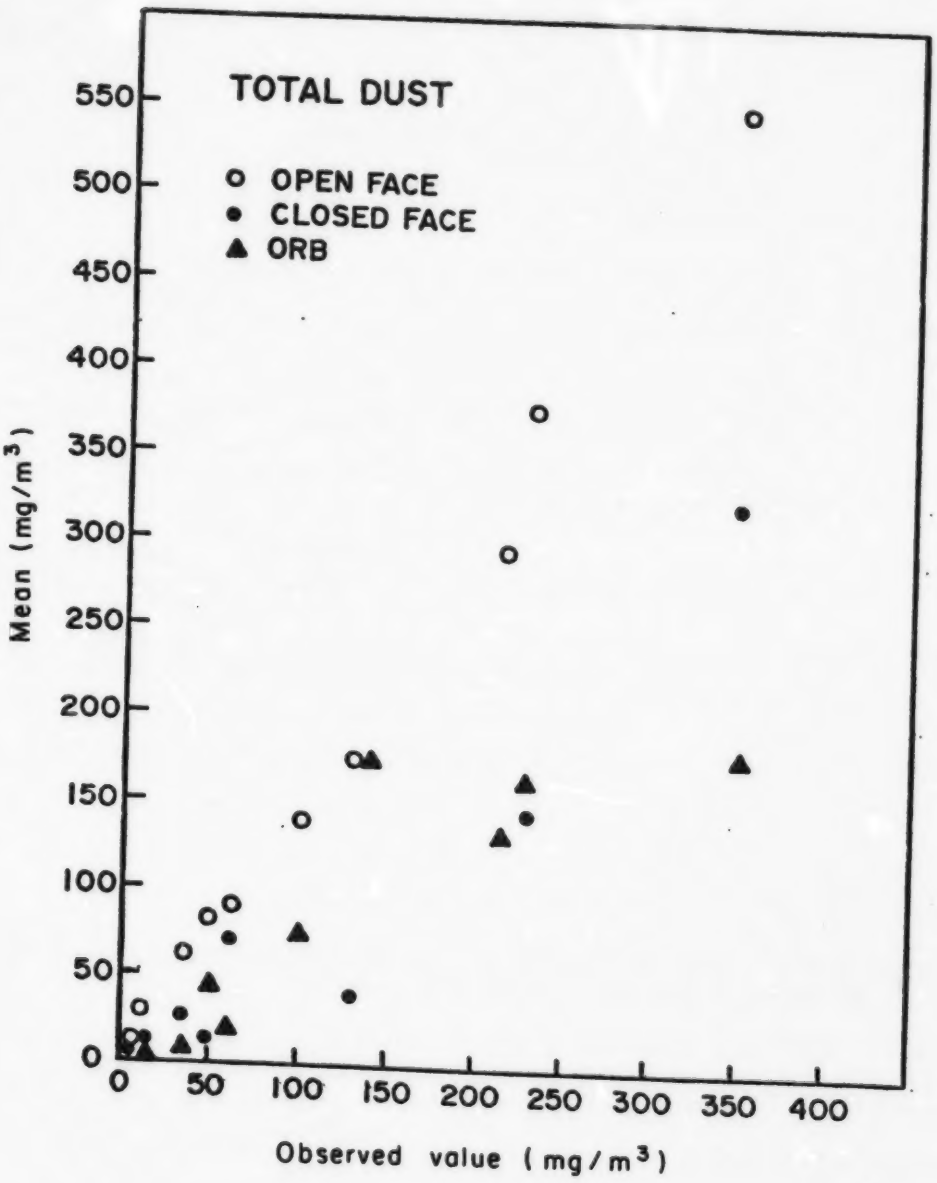

Fig. 5-1 - Total dust observed by three types of dust samplers.

3.7 ABSOLUTE CONVERGENCE MEASUREMENTS IN POTASH MINE OPENINGS

SCIENTIFIC AUTHORITY: G. Herget

CONTRACTOR: Cominco Ltd., Potash Operations, Vanscoy, Saskatchewan — $41 717.

WORKSCOPE:

1. Establish a reliable benchmark in the shaft area.
2. Install survey stations at 100 m intervals along the permanent access of the 300 Entry East systems.
3. Install two multiple point extensometers at two suitable locations on the upper mining level and at one on the lower level. One extensometer would extend 12 m into the back, while the other would extend 45 m into the floor.
4. Install closure stations at each site.
5. Monitor the extensometers and closure stations at a frequency relative to the closure rates being experienced.
6. Conduct a precise levelling survey after completion of installation of the extensometers and closure stations, and determine their true elevations.
7. Repeat precise levelling surveys after three and nine months, and calculate new true elevations. Surveys will be continued, after completion of the contract, at Cominco's cost.
8. Assess movements of floor and back, then prepare and submit a report.

OBJECTIFS:

1. Établir un point repère sûr dans la zone du puits.
2. Aménager des stations de contrôle à tous les 100 mètres dans la voie permanente d'accès aux systèmes est de l'entrée 300.
3. Installer deux extensomètres à points multiples à deux endroits convenables, un au niveau supérieur de la mine et un au niveau inférieur. L'un pénètrerait à 12 m dans le toit, et l'autre, à 45 m dans le plancher.
4. Aménager des stations de fermeture à chaque endroit.
5. Contrôler les extensomètres et les stations de fermeture à une fréquence proportionnelle aux taux de fermeture réels.
6. Faire un relèvement précis des niveaux après l'installation des extensomètres et l'aménagement des stations de fermeture et déterminer leurs altitudes vraies.

7. Répéter le relèvement précis des niveaux après trois mois et après neuf mois, et calculer les nouvelles altitudes vraies. Des relèvements des niveaux seront faits après la fin du contrat, aux frais de Cominco.

8. Évaluer les mouvements du plancher et du toit, puis préparer et soumettre un rapport.

RESULTS:

D. MacKintosh, project manager for Cominco Ltd., attended the seminar and presented the following report:

Salt and potash deformations are time-dependent and a long time is required to adequately evaluate a mining layout in situ. A design error may not be displayed until several years after the layout has been cut. To ensure continued safe operations, a better understanding of the long-term implications of mining and the reaction of overlying strata, in particular the Dawson Bay limestone, to different panel and pillar layouts is required.

In order to gain some estimation of the characteristics of a particular design without actually cutting it, a predictive model needs to be used. Such a model should firstly: confirm that continued use of present designs does not jeopardize the long-term stability and safety of the mine, and allow continued safe recovery of the resource. Secondly, the model should be used as a design tool to analyze alternative mining layouts in order to safely maximize extraction.

To gain confidence in such a tool, it must first be verified by comparing deformation predictions with known field data.

There has been a tremendous amount of field data collected in the potash industry over the last 10 to 15 years. Unfortunately, very little has been made available to researchers outside the industry. In fact, until recently, there has been very little exchange of technical information between potash mining companies.

At the potash operations of Cominco Ltd., Vanscoy, Saskatchewan an entry system was cut in an isolated area and instrumented during the period from January to June 1984 at a depth of approximately 1100 m. This area was not subjected to any reloading influence from other mining activities and was left completely unsupported. The deformations observed show a characteristic response of openings to in situ ground stress conditions.

An important aspect of the program was the attempt to determine the absolute contribution of back and floor movements to the total convergence. That is, the per cent total closure attributable to the back moving downwards and the per cent due to the floor moving upwards.

Figure 7-1 shows the location of the project site. This is in the main entry development to the new Cominco Ltd. mining block which will use a retreat mining technique. This means the project site will be left to itself for many years without suffering the effects of reloading. As the entry layout is symmetrical, the east half was intensively instrumented to monitor cumulative room closure, internal pillar, back, floor and abutment deformations, and stress levels.

Pressure cells and borehole extensometers were placed 30 m (100 ft) into the infinite wall rock, 10 m (30 ft) into the back and 30 m (100 ft) into the floor, as well as through the yield pillars (Fig. 7-2).

Figure 7-3 shows the closure rate in the first room (2105). The reloading response to cutting the second room (2101) can be seen. The second room is

approximately 45 m away from the first room. Of note is the difference between centerline and rib rates, the centerline being two times the rib rate.

Figure 7-4 shows the total vertical room closure observed along the ribs as the entry system was developed. The reloading of room 2105 by cutting room 2101 cannot readily be seen on this scale.

Figure 7-5 shows the expansion observed in the infinite wall rock to a depth of 30 m (100 ft). It can be seen that most of the movement is taking place in the first 8 m (25 ft).

Yield pillars were instrumented throughout their total width. Excellent strain distribution patterns and total expansion records were obtained. Figure 7-6 shows the creep distribution in micro-inches/hour/foot observed in the yield pillar between rooms 2104 and 2105. The deformation peak does not respond to the pillar centerline but is skewed towards room 2104. This has been found to be typical of pillars adjacent to relief drifts.

Figure 7-7 shows a similar distribution in the pillar between rooms 2103 and 2104. Here the deformation center corresponds to the pillar center.

The floors of these rooms were instrumented to 30.5 m (100 ft). Problems with these extensometers throughout the project resulted in poor records of floor deformations. Revised reading methods appear to be providing reasonable results; however, these sites are to be replaced. Figure 7-8 compares the expansion observed in the floors of rooms 2103 and 2104. Expansion extends deeper into the floor of the wider room 2103.

Figure 7-9 provides an example of the horizontal closure rate.

Pressure cells provided by the Saskatchewan Research Council were installed at various depths to 9 m (30 ft) into the back, 30.5 m (100 ft) into the floor, in the yield pillars, and up to 30.5 m (100 ft) into the abutment. Although several cells failed at various times throughout the project period, results are considered to be of significance, in particular, the outlining of a higher stress concentration approximately 6 m (20 ft) above and 15 m (50 ft) below the centre of the entry system. Figure 7-10 shows the results observed with a pressure cell installed in the pillar between rooms 2104 and 2105. These cells are usually pre-stressed to approximately 2000 psi. The initial ground response reduces the pressure somewhat, then pressure increases, similar to a creep curve, until it stabilizes at what is accepted to be the stress level present at the cell location.

The cell displayed in Fig. 7-10 was installed prior to cutting room 2104. The large jump from day 9 to day 11 occurred during cutting of room 2104. The pressure appears to stabilize very quickly after that at approximately 4500 psi, then drops off slowly with time. This is not thought to be a failure of the cell but may reflect load being shed by the yield pillar.

Figure 7-11 shows an example of a pressure cell which is just showing signs of stabilizing after over 150 days.

Extensometer results from this pillar indicate a strain of 0.4 in./ft at this cell location. Whether or not the resin matrix around the flat jack pressure cells can withstand such tensile strains is an area of concern. It is pro-

posed to replace this cell with a similar type, but containing strain gauges, to get a better understanding of what may be happening in the cells.

The major problems encountered in the project have been pressure cell failures, and an unexpected response from borehole extensometers installed in the floor. It has not been possible to account for a significant proportion of the total room closure in the 40 m (130 ft) being monitored. There is an indication that the floor anchors are binding each other or slipping in the hole. An alternative system will be installed.

An important aspect of the project has been to attempt to determine the absolute closure contributed by roof and floor. To do this, a precise level survey of the project site was undertaken, with reference to the shaft's concrete lining. Level surveys from the shaft to the project site were carried out first in July 1984, then in October 1984, and February 1985. Results indicate an average of 21 per cent of the total room closure is contributed by roof subsidence. This is a preliminary figure and subject to revision as more data become available.

In an infinite homogeneous rock one would expect back and floor movements to contribute equally to the total closure. However, the potash beds are close to the top of the evaporite formation, and the close proximity of the relatively stiff limestone member will influence greatly the proportions of back and floor movements.

If the limestone made up the immediate back, the per cent closure observed in the opening contributed by the floor would approach 100 per cent. Similarly, if the openings were at the bottom of the evaporite and the limestone made up the immediate floor, the contribution of the back would be expected to approach 100 per cent.

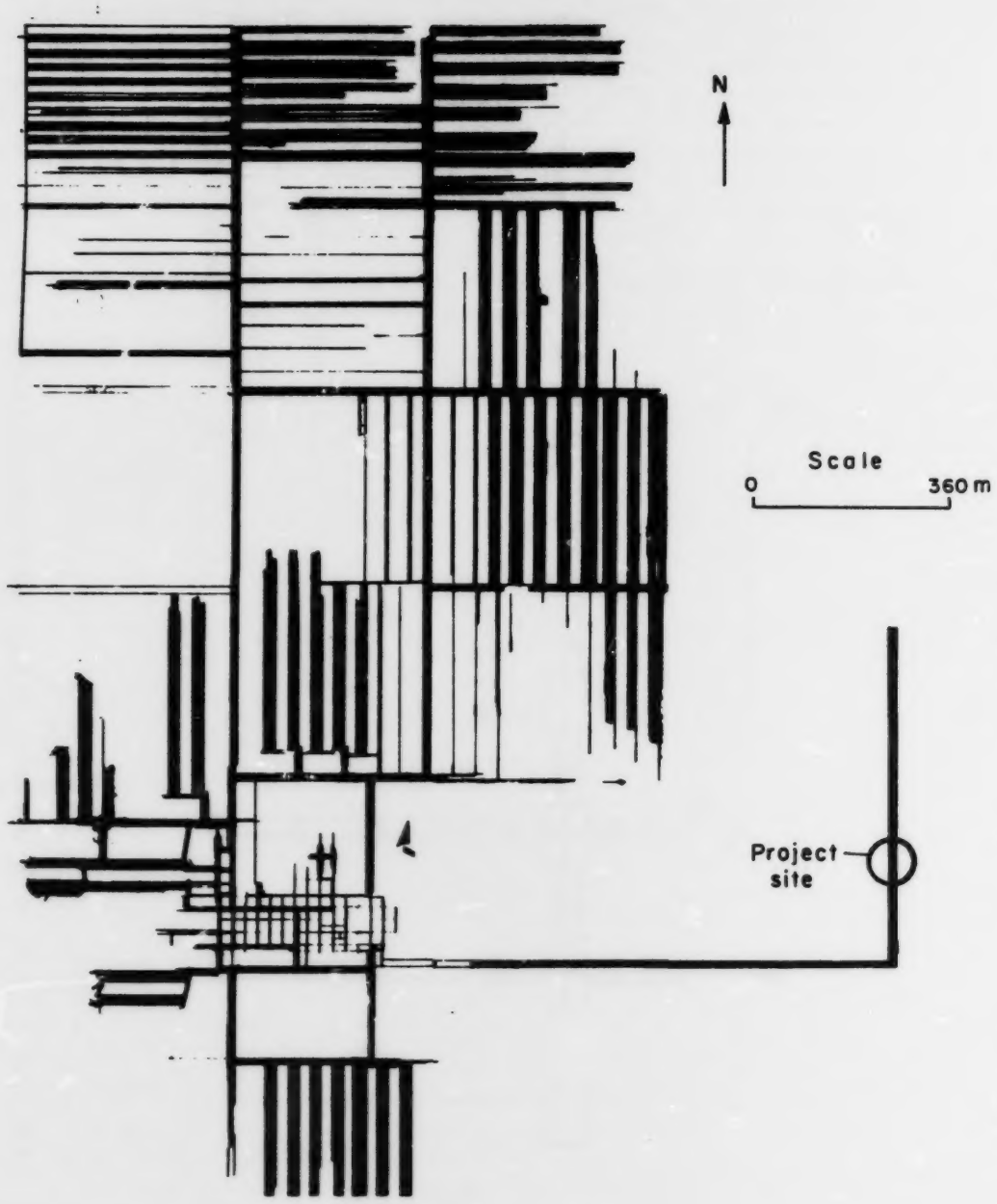

Fig. 7-1 - Mining plan and location of project site at 1100 m (Cominco Ltd.)

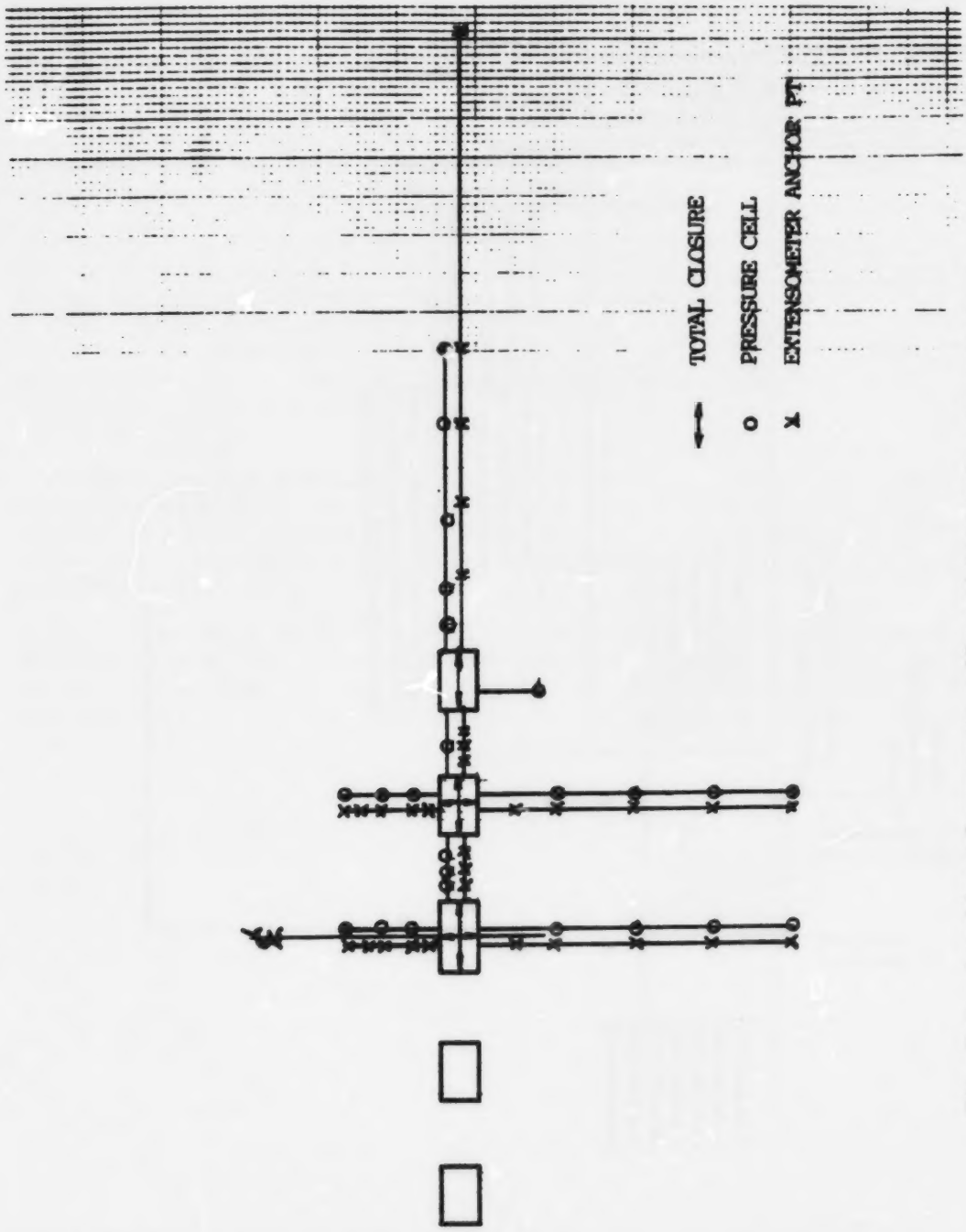

Fig. 7-2 - Location of pressure cells and bore hole extensometers

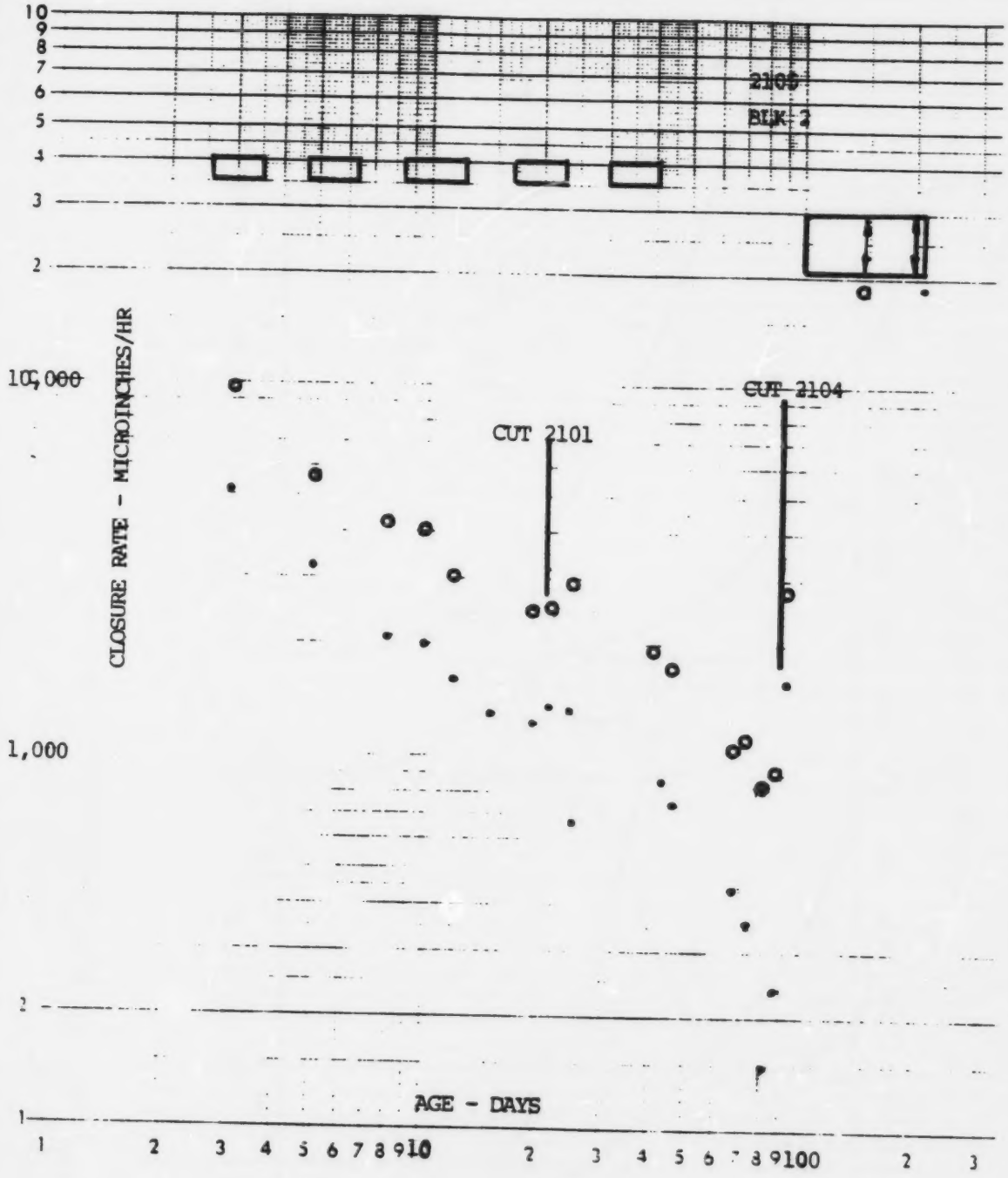

Fig. 7-3 - Closure rate of first room (3105)

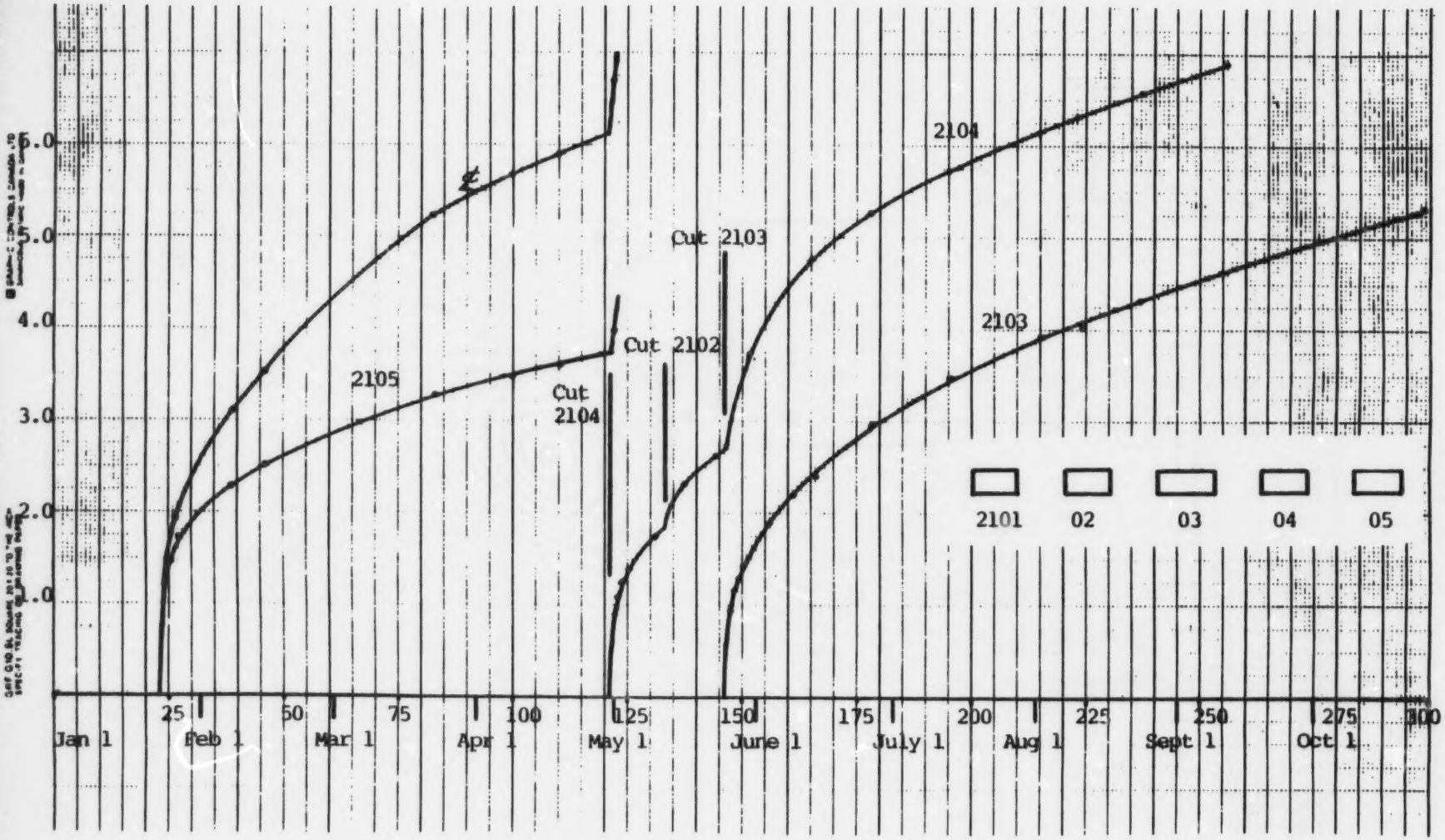

Fig. 7-4 - Total vertical room closure

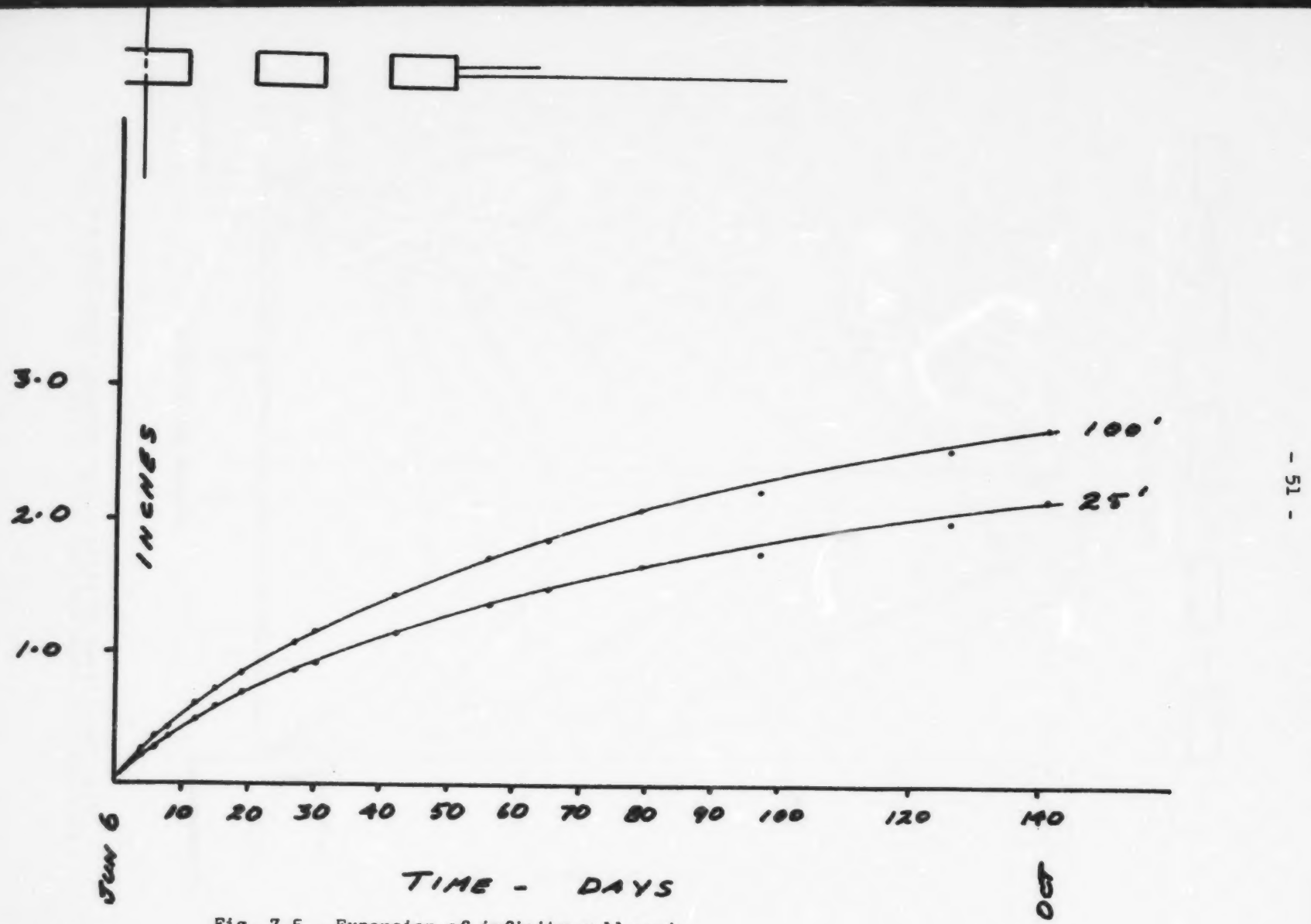

Fig. 7-5 - Expansion of infinite wall rock

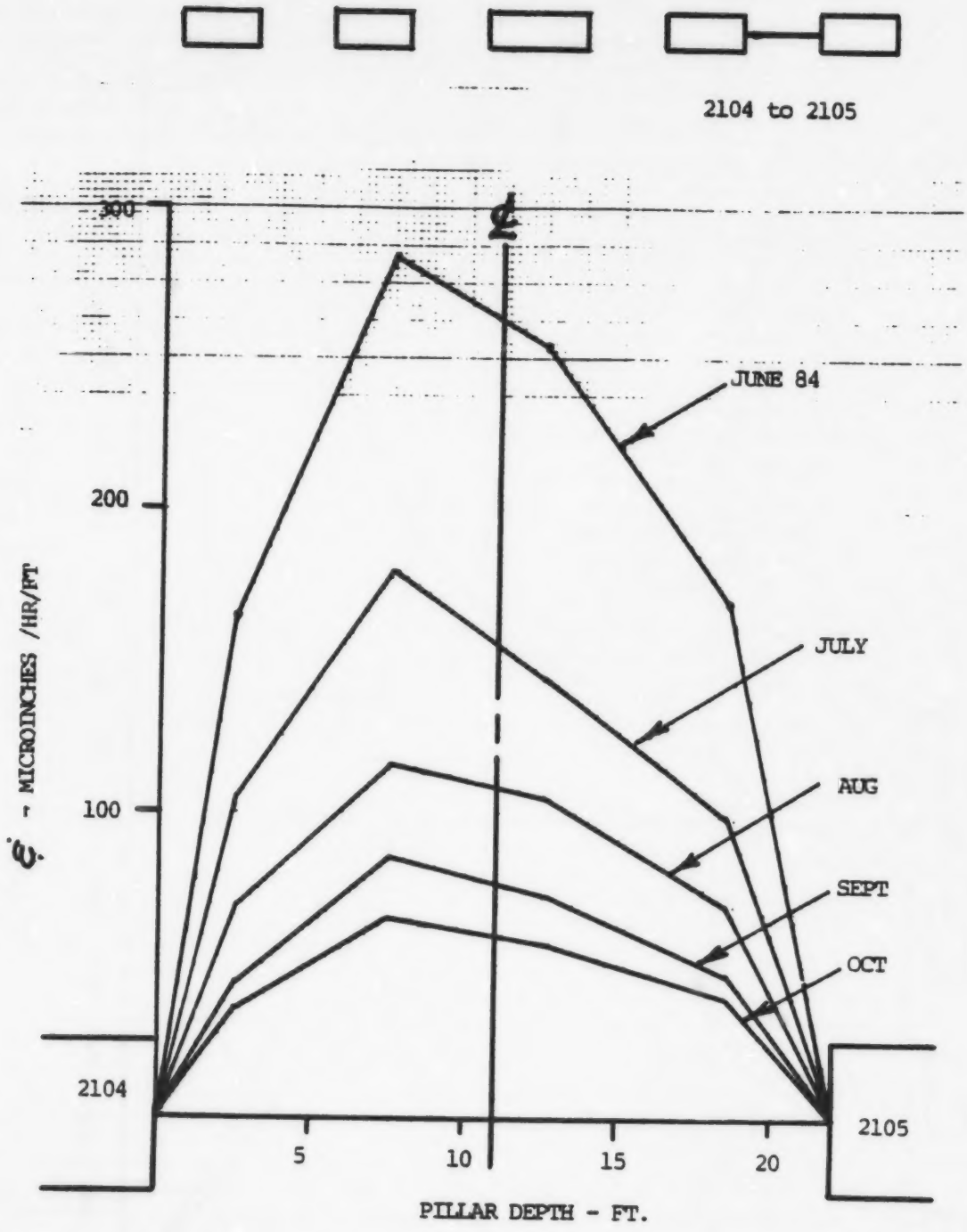

Fig. 7-6 - Creep of yield pillar between rooms 2104 and 2105

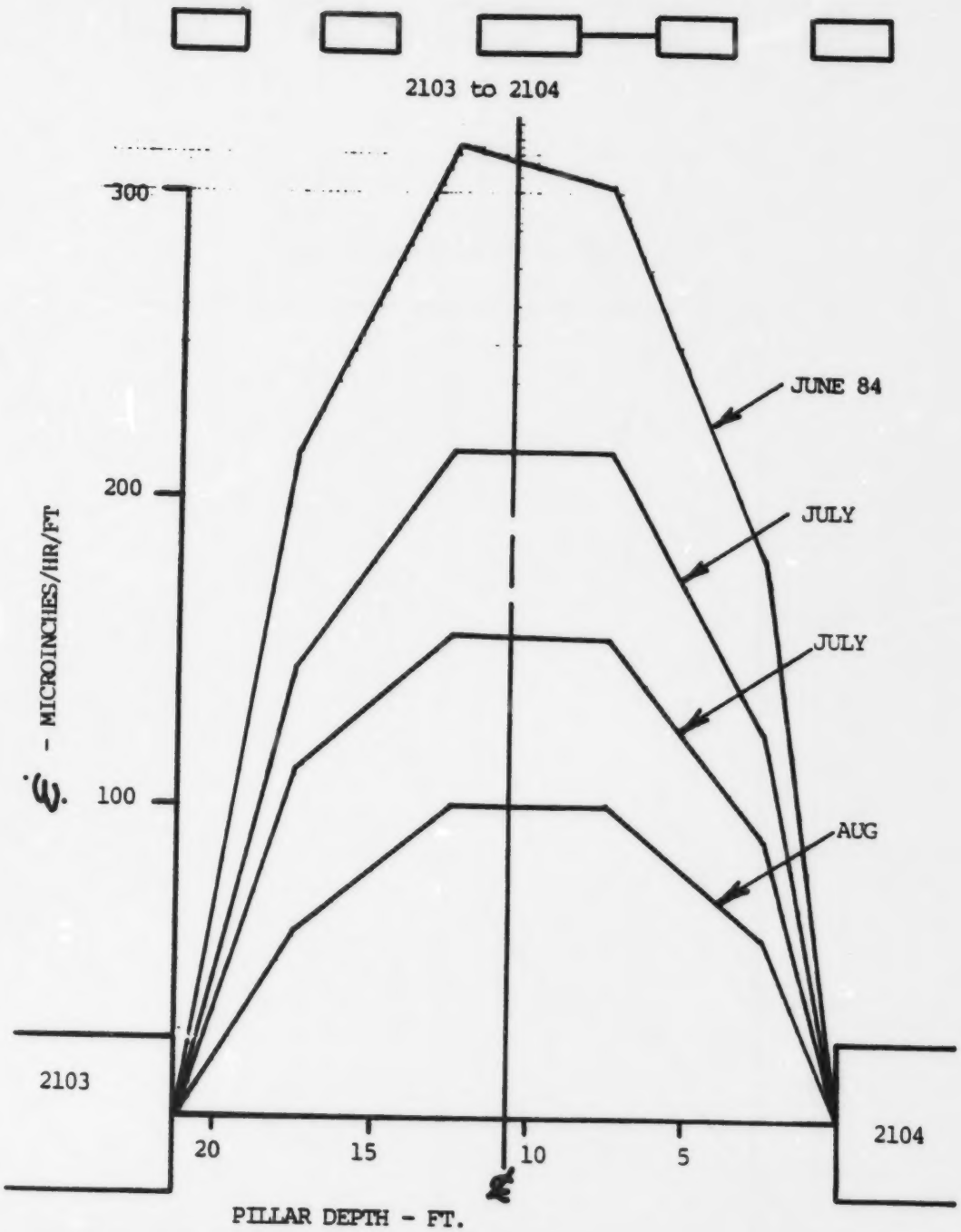

Fig. 7-7 - Creep of yield pillar between rooms 2103 and 2104

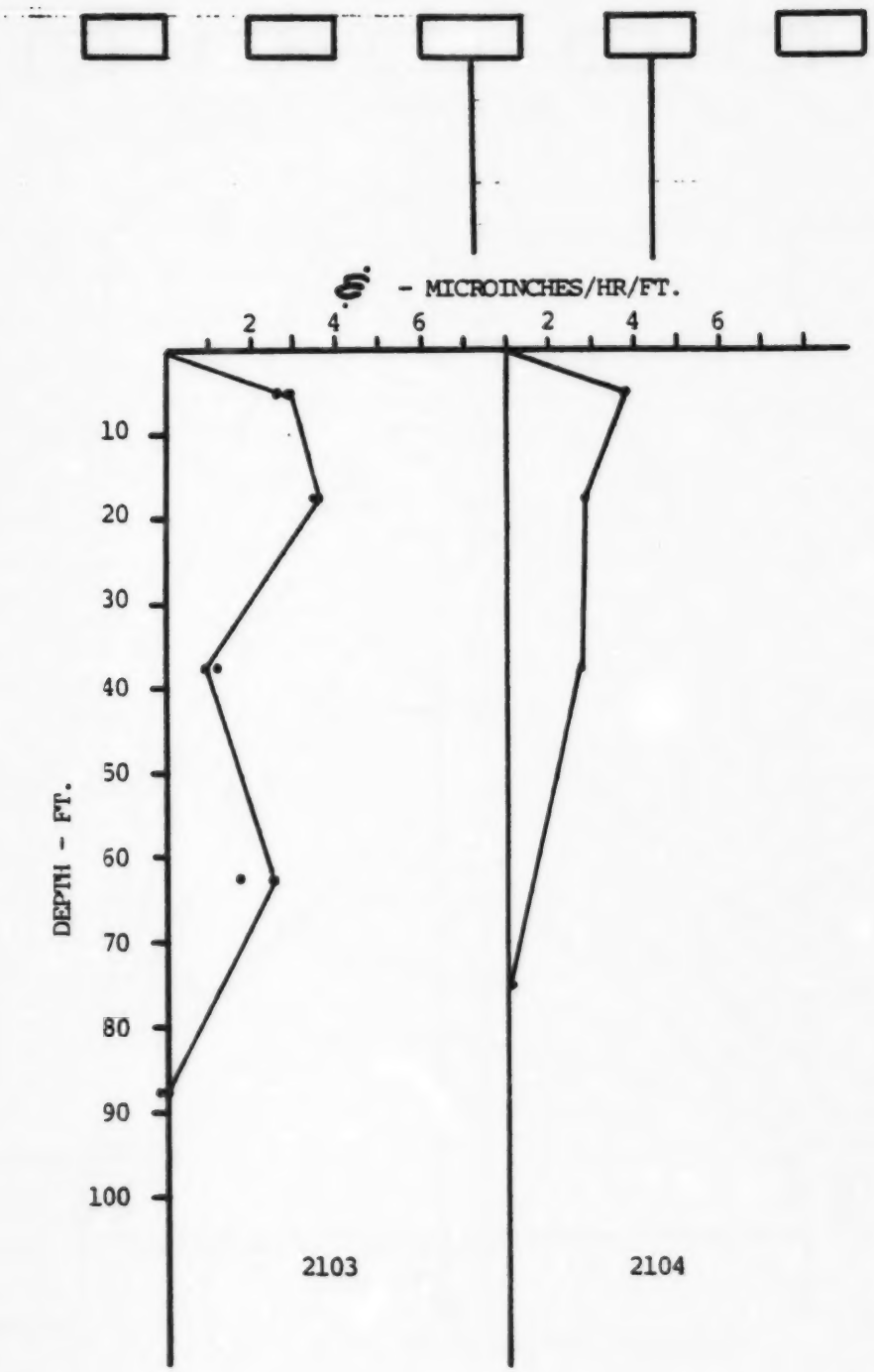

Fig. 7-8 - Expansion of floor for rooms 2103 and 2104

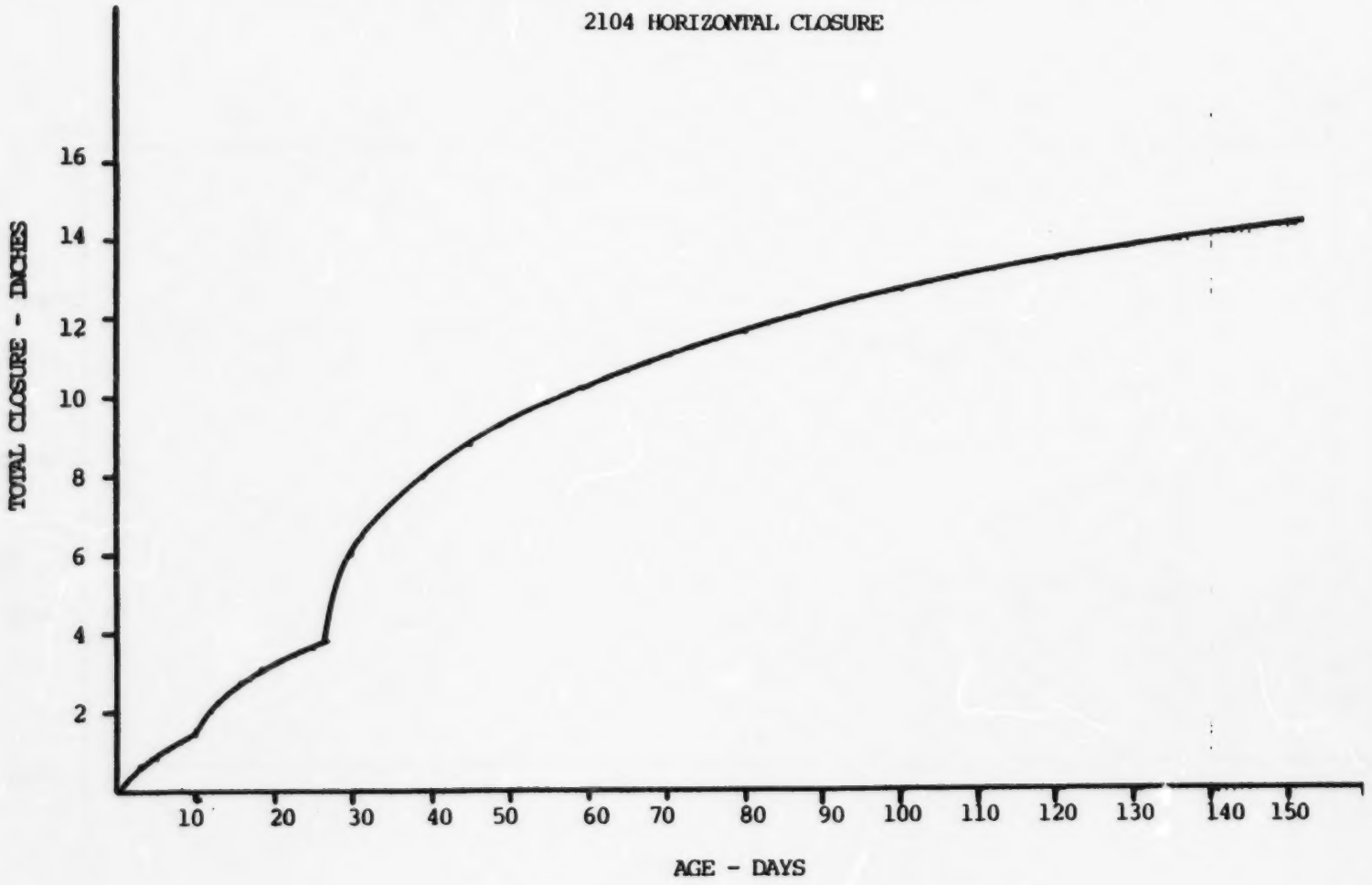

Fig. 7-9 - Horizontal closure rate in room 2104

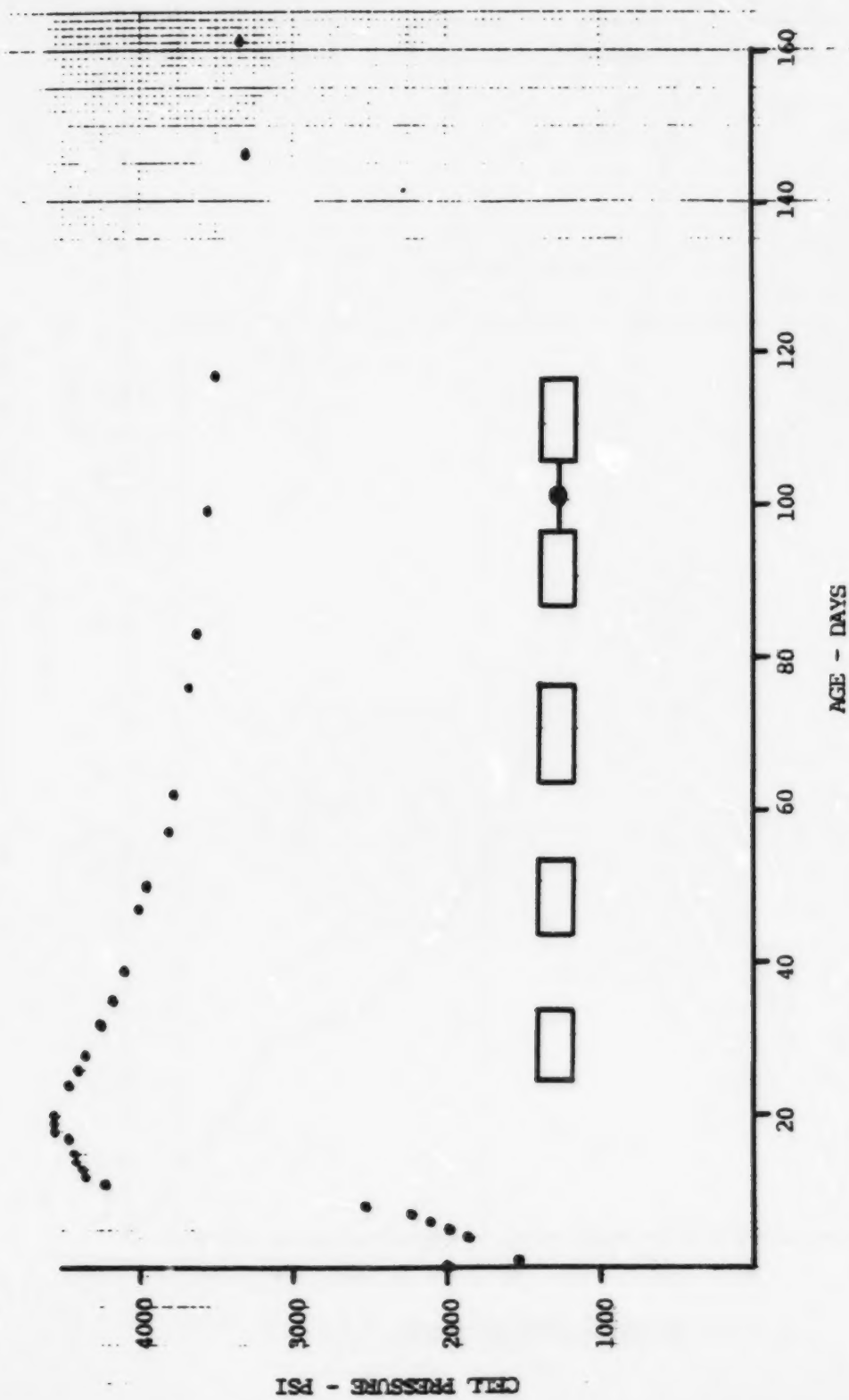

Fig. 7-10 - Pressure change in yield pillar between rooms 2104 and 2105

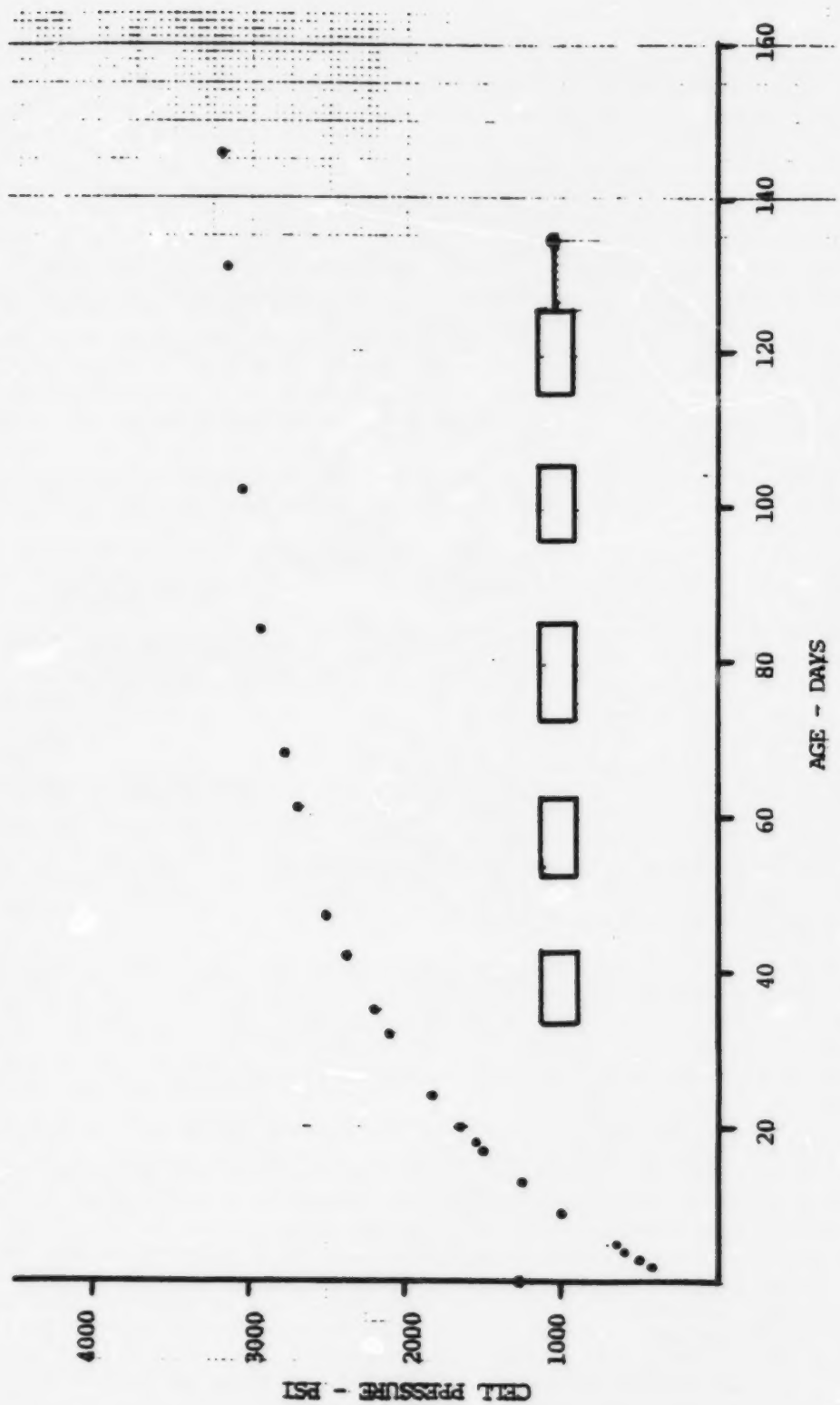

Fig. 7-11 - Record of pressure cell in infinite wall

3.8 A FIELD TEST PROGRAM TO EVALUATE THE USE OF WASTE SALT BACKFILL IN SASKATCHEWAN POTASH MINES

SCIENTIFIC AUTHORITY: G. Herget

CONTRACTOR: Central Canada Potash, Colonsay, Saskatchewan — $120 000.

WORKSCOPE:

1. Develop access to areas with hanging wall brine leaks for grouting and backfilling by Voest-Alpine AM-50.
2. Grout Dawson Bay formation.
3. Open remainder of test area.
4. Instrument the test area and a borehole in the Dawson Bay formation to determine water pressure, deformation of overlaying strata, and convergence of excavations.
5. Backfill the area by pneumatically stowing with crushed salt muck.
6. Monitor water pressure and convergence after backfilling and carry out analysis of the data obtained during the first 12-month period.

OBJECTIFS:

1. Rendre accessible les zones dont l'éponte supérieure présente des fuites de saumure pour y injecter du ciment et remblayer à la Voest-Alpine AM-50;
2. Injecter du ciment dans la formation de Dawson Bay;
3. Ouvrir le reste de la zone d'essai;
4. Installer des instruments dans la zone d'essai et dans un trou foré dans la formation de Dawson Bay pour déterminer la pression de l'eau, la déformation des strates sus-jacentes et la convergence des excavations;
5. Remplir la zone par remblayage pneumatique avec des déblais de sel broyé.
6. Contrôler la pression de l'eau et la convergence après le remblayage et l'analyse des données obtenues au cours de la première période de 12 mois.

RESULTS:

At the time of the seminar, the contract work was not complete and cutting access into some of the instrumentation sites was still in progress. The bulk of instrumentation was still to be installed.

Alan Coode, Chief Mine Engineer of Central Canada Potash and W.F. Bawden of Noranda Research, Pointe Claire, Québec elaborated on the work which had been completed. A site visit to Central Canada Potash to look at water occurrences in the hangingwall and footwall and the in situ work completed was organized by A. Coode, Chief Mine Engineer for November 22, 1984.

The areas with water inflow are located in panels 109 and 209. Figure 8-1 shows their location on a mine plan. These sites have experienced considerable convergence since they were originally opened up. Figure 8-2 shows how convergence has occurred primarily by floor heave.

1. Grouting

The overlaying Dawson Bay formation will be grouted to divert brine from the existing inflow area. Selected sections will be instrumented and the test areas will be backfilled.

During this operation, work will be required to provide adequate ventilation, temporary muck storage, electrical power, compressors, piping, drainage and communication.

2. Instrumentation of backfill and surrounding strata

A critical part of the proposed research program involves the study of the interaction of the backfill with the surrounding salt and potash seams. It is anticipated that the backfill will act to reduce the closure rates and affect stress redistribution in the surrounding strata.

The final mine closure and stress redistribution are ultimately manifested as surface subsidence. The amount and pattern of surface subsidence is related to the deformation of the overlying strata between the mine workings and ground surface. Hence, all of the above will affect the long-term behaviour of the Dawson Bay formation. Ultimately, it will be the ability to predict and control the deformation behaviour of the Dawson Bay formation that may allow the use of an increased extraction ratio in Saskatchewan potash mining.

During the grouting and backfilling stage, instrumentation stations will be selected and monitoring instruments installed. Instrumentation will include closure meters in the rooms, earth pressure cells and piezometers in the backfill, load and deformation meters in the host salt and potash formations, and stress meters in the Dawson Bay formations. At least one section in panel 109 and up to four sections in panel 209 will be fully instrumented. Instrumentation of the Dawson Bay formation will depend on the degree of difficulty encountered in drilling the instrumentation holes. All instrumentation will be connected to data acquisition systems for long-term monitoring.

Since the proposed backfill area in panel 209 is significantly larger than panel 109, the former has been selected as the prime instrumentation site. In panel 209 four instrumentation stations will be installed. Each station will include a closure meter in the room, two earth pressure cells and a piezometer in the backfill, two Multiple-Anchor Borehole Extensometers (MBX's) (one at the roof and the other at the floor), and one pressure cell in the abutment pillar. All of this instrumentation will be fed to an OTRONA portable data logger and microprocessor for continuous monitoring.

In panel 109, a single central instrumentation station will be installed similar to those described for panel 209. If sufficient funding is available, additional instruments will be installed near the end of the panel. This instrumentation will be fed into a separate OTRONA portable data logger and microprocessor for continuous monitoring. The purpose of instrumenting panel 109 is to determine whether any significant difference in behaviour occurs between the two backfilled test areas.

3. Instrumentation of the Dawson Bay formation

Long-term closure of the potash mine rooms is ultimately expressed as surface subsidence. The observed surface subsidence is then related to deformation and stress redistribution in all of the overlying strata between the mining horizon and ground surface.

As part of the grouting program at least two boreholes will be drilled into the Dawson Bay formation. An attempt will be made to install at least one, and hopefully more than one, stress meter in each hole to monitor stress redistribution during room closure.

At present, it is planned that the above instrumentation will be placed in the panel 209 area.

4. Backfill physical parameters

Tests will be done on selected samples of the backfill, to determine basic physical parameters for analysis of the results of the overall backfill test and to determine the degree of heterogeneity, if any, in the backfill material used. The test program will include the following:

- grain size analysis (sieve analysis)
- density
- mineralogy (including clay content)
- moisture content
- compressibility tests
- creep tests.

Most of the above tests can be done at CCP. However, the compressibility and creep tests may require the facilities of the University of Saskatchewan or the Saskatchewan Research Council.

5. Data analysis

The cooperatively funded project will be continued for a period of two calendar years.

At the end of the above period, the available data will be analyzed as completely as possible. This analysis will be aimed at evaluating the influence of backfilling on closure, stress redistribution and the behaviour of the Dawson Bay formation.

6. Summary of activities for 1984

In 1984, approximately seven months were spent on rehabilitation work and development of access to the two test areas, Panels 109 and 209 (Fig. 8-1). Approximately 5000 m (16 500 ft) of access was rehabilitated. Most of the rehabilitation work was performed using a Voest-Alpine AM50 and one 5 yd^3 scooptram. Blasting, bolting and resin anchoring were necessary in some areas. Typical convergence is shown in Figure 8-2.

In Panel 209 approximately 655 m (2150 ft) of access into the test areas was developed and the drilling stations established (Fig. 8-3). In some areas, artificial ground support had to be installed, consisting of mechanical bolts or cribs. The existing drill holes were logged and geological cross-sections prepared.

The instrumentation was then designed to provide the most detailed information about the interaction of the backfill with the surrounding formations. These instruments will be arranged as shown schematically in Figure 8-3.

Primary grout holes 84-9 and 85-1 to 85-4 were drilled, totalling 569 ft (Fig. 8-3).

Holes 84-9 and 85-2 will be instrumented, each with one stressmeter and two strain gauges.

Two deep pin stations and eleven room closure stations were designed and installed as a means to monitor closure rates along the access development prior to backfilling. These stations have shown vertical and horizontal closure rates averaging 0.30 in./100 days and 0.49 in./100 days, respectively.

The first set of instruments was installed. A roof and a floor extensometer and a convergence meter were installed in W54N between N6 and N7 (Fig. 8-3) as part of a permanent instrumentation station.

One borehole pressure cell station was designed and installed. It consists of three pressure cells, distributed at different depths along the barrier pillar.

A series of pump tests was performed in order to establish the brine inflow rate, which was found to average 81 L/min (18 igpm).

In Panel 109 the access development was established and the primary grout holes and instrumentation stations designed. A schematic layout of the work planned and developed in this test site is shown in Fig. 8-4.

Four of the primary grout holes were drilled totalling 533 ft. Two of these holes (shown as 84-2 and 84-3 in Fig. 8-4) will be instrumented.

Two room closure stations and one deep pin station were installed as a means to pick up the early stages of closure, prior to the installation of the permanent instrumentation stations and to backfilling. Those stations have shown predictable vertical and horizontal closure rates averaging 8.6 mm/100 days (0.34 in./100 days) and 11.4 mm/100 (0.45 in./100) days, respectively.

A series of measurements of brine inflow rates in Panel 109 has shown an average value of 13 L/min (2.9 igpm).

Most of the instruments to be installed in Panels 109 and 209 were purchased, at a total cost of $2137.59.

The CANMET borehole TV camera was tested to log the instrument holes in Panels 109 and 209. The camera seals, however, were not adequate for the harsh salt environment and the camera could not be used.

The McPhar Stress Alert Rock Monitor was tested at PCS-Rocanville but showed inconsistent results.

CONCLUSION

The results achieved during this project were very encouraging and are fundamental for the development of the second phase of the project. In the first quarter of 1985, instrumentation was installed and the grouting program was initiated with success. The primary grouting program was designed to establish a grout curtain in the back in Panel 209. A successful completion of the second phase, which consists of grouting, instrumentation and backfilling, is expected.

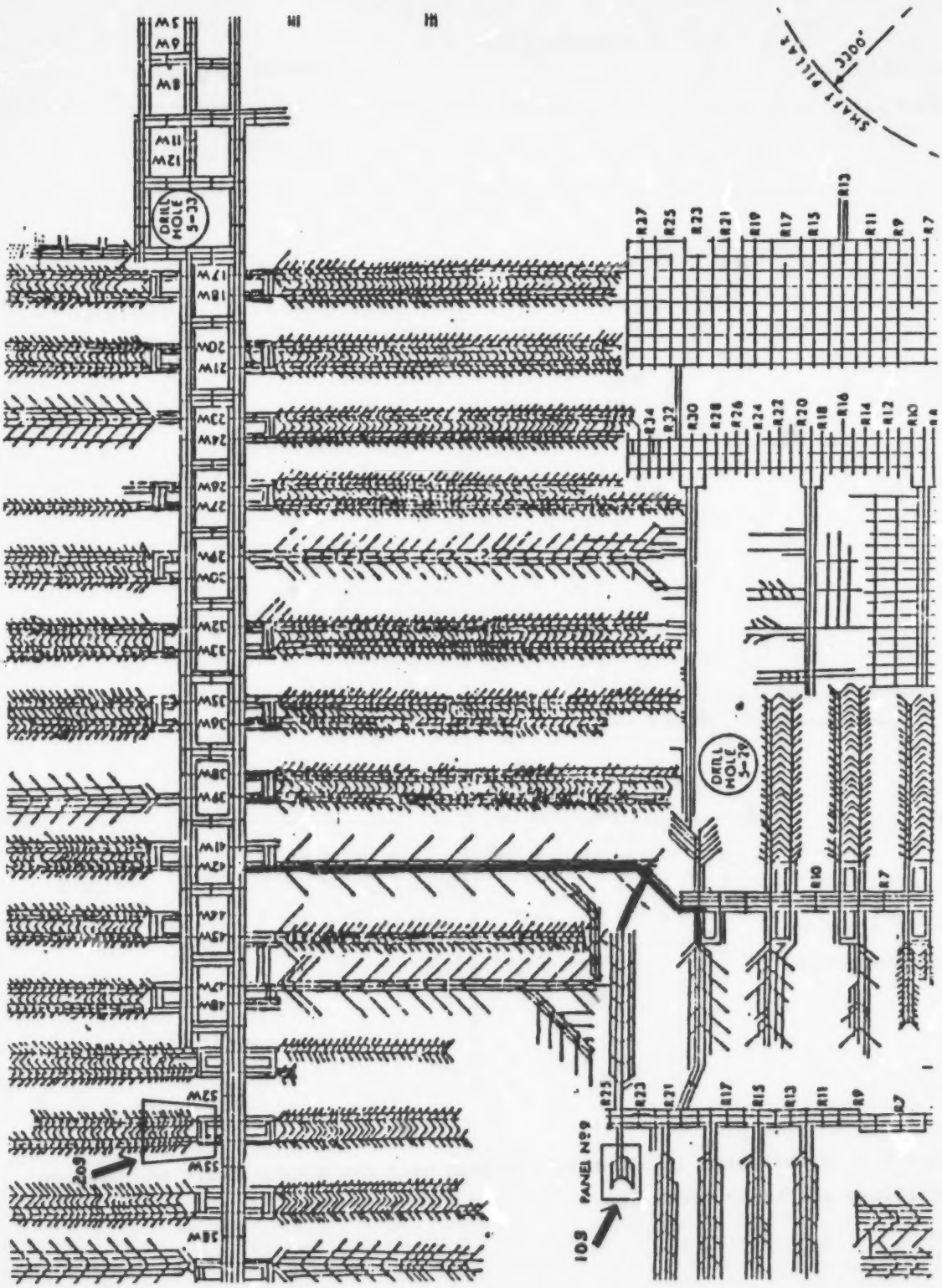

Fig. 8-1 - Location of test areas

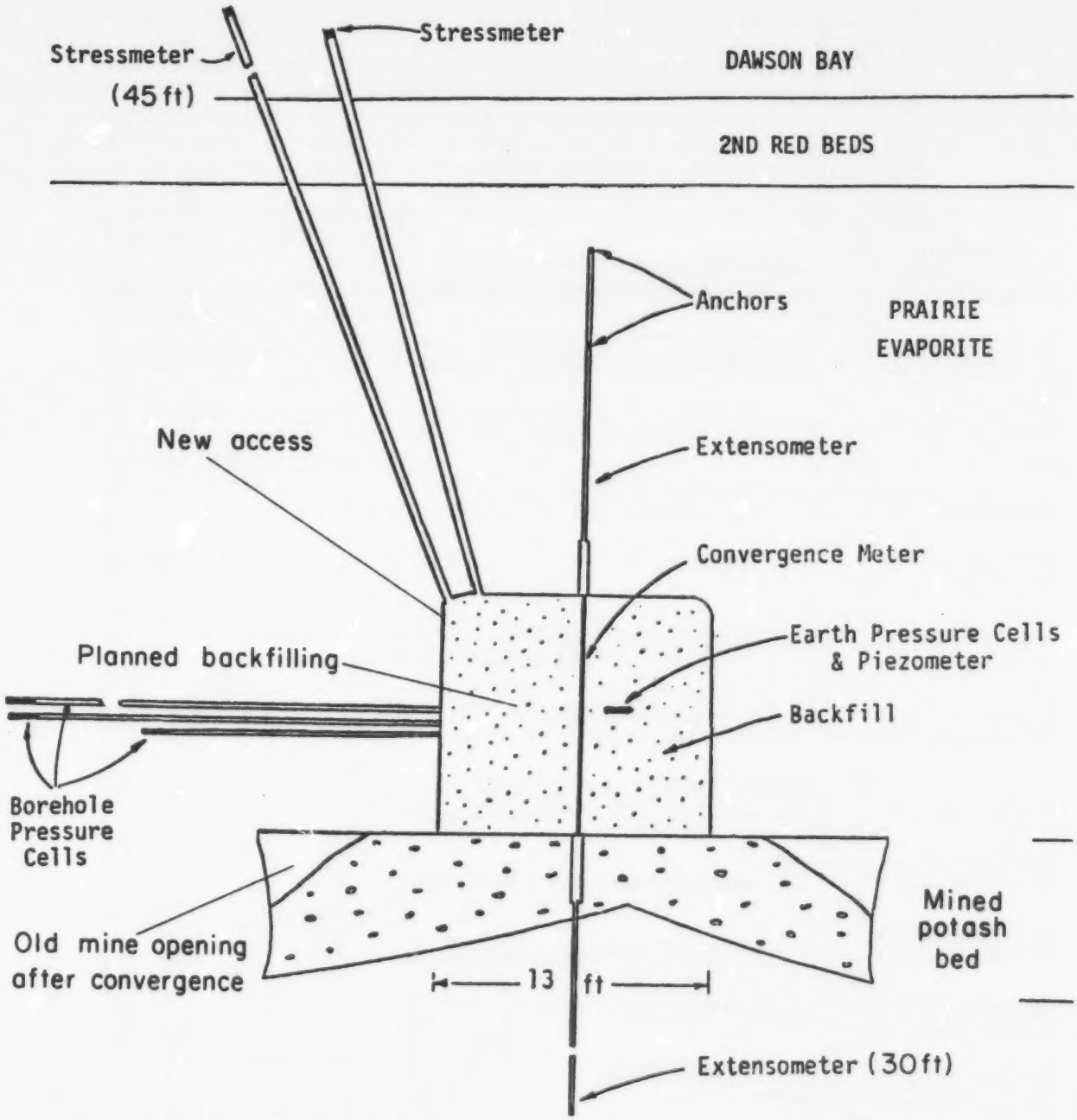

Fig. 8-2 - Convergence in old mine openings with new access drift and planned backfilling and instrumentation

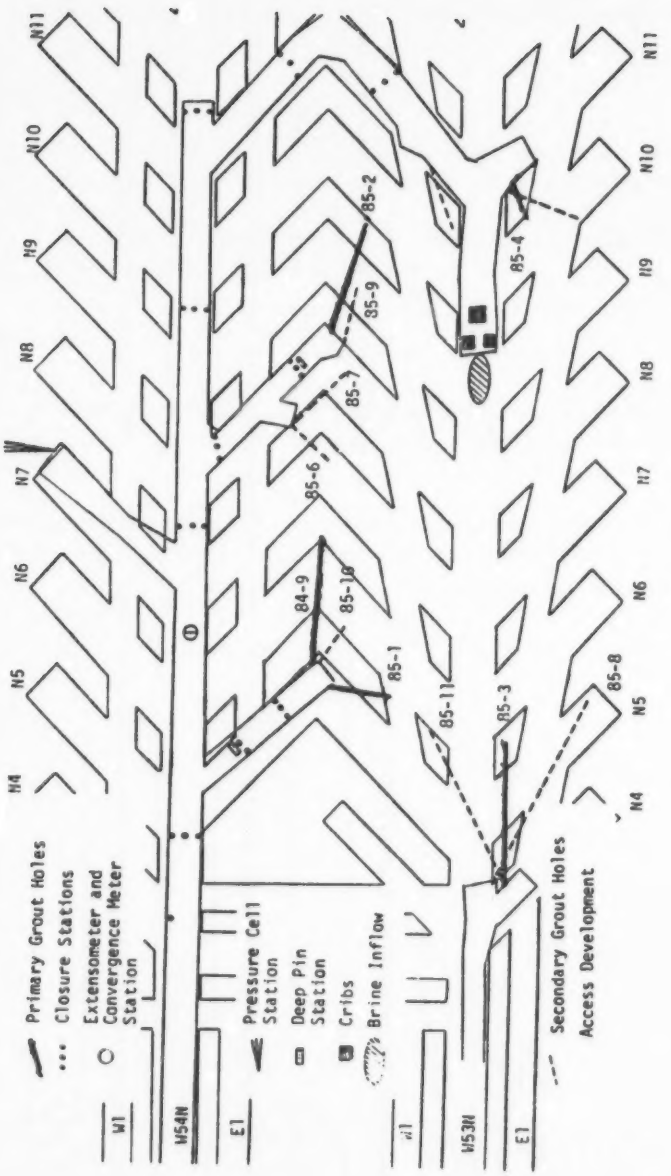

Fig. 8-3 - Access development and instrumentation - Panel 209

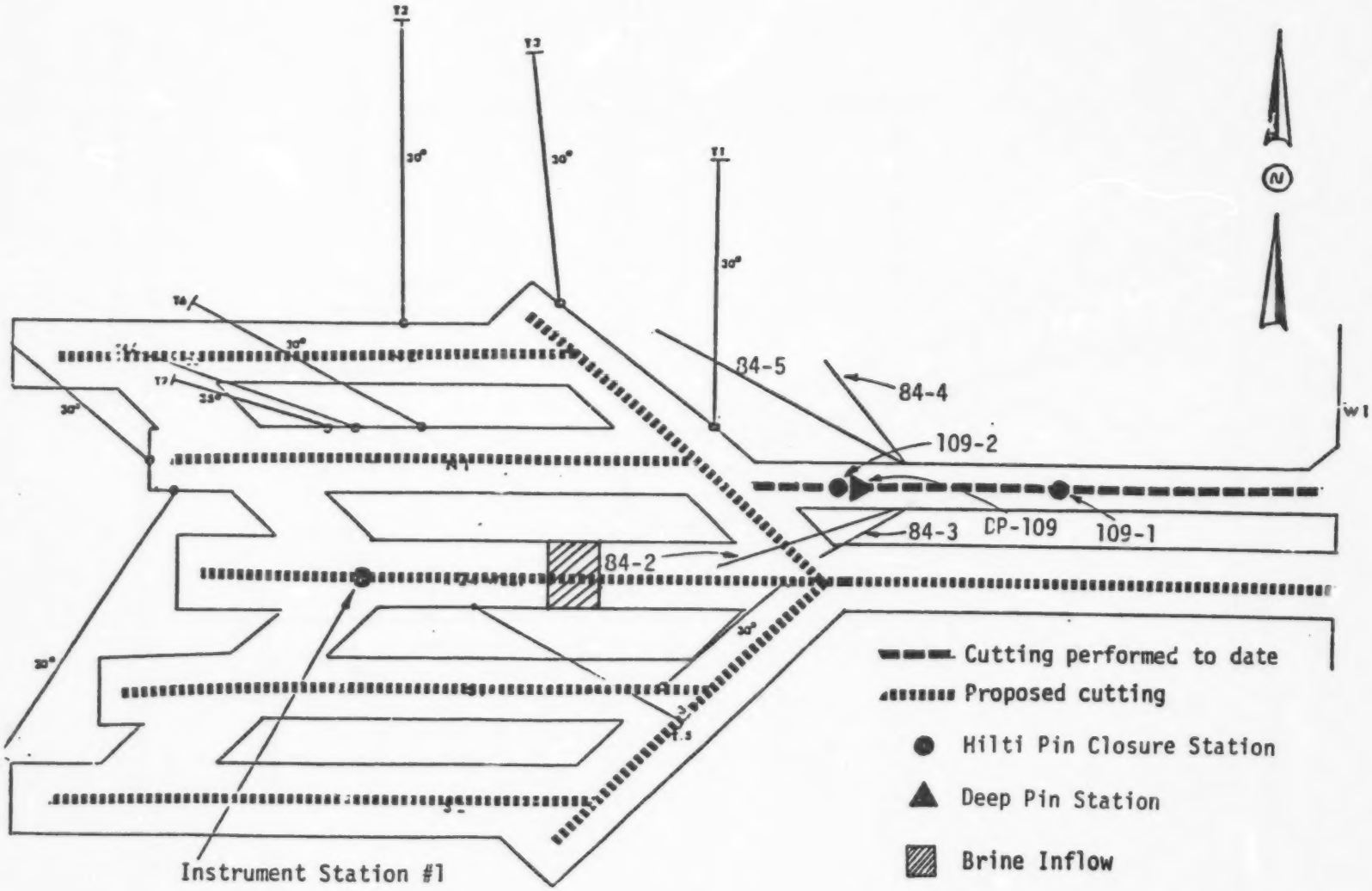

Fig. 8-4 - Access development and backfill instrumentation design for Panel 9, Rm. 24 West

4. FACILITIES AT THE UNIVERSITY OF ALBERTA FOR TESTING OF POTASH

Dr. P.K. Kaiser, Professor of Civil Engineering, Department of Civil Engineering, University of Alberta, Edmonton, Alberta.

PURPOSE OF PRESENTATION:

1. To inform about existing test facilities that could be applied to investigate the behaviour of underground openings in potash mines.

2. To indicate how these facilities and capabilities could be used to supplement current research efforts.

PRÉSENTATION

1. Fournir des renseignements sur les installations d'essai existantes en vue d'une recherche sur le comportement des ouvertures souterraines dans les mines de potasse

2. Indiquer comment ces installations et ces ressources peuvent être utilisées pour compléter les efforts actuels de recherche.

During the presentation of some of the contract work in progress, it was suggested that pressuremeter testing to determine in situ rock mass properties and model tests on circular openings in potash could be used effectively to bridge gaps in the interpretation process, when linking laboratory test results from small samples with predictions made by numerical modelling, and data collected during field monitoring. Pressuremeter tests can provide in situ rock mass properties. Tests on large blocks (600 x 600 x 200 mm) would provide data for comparison with regular laboratory test results to assess scale effects on creep properties. Scale model tests on small openings could then be employed to evaluate the predictive capacity of new numerical techniques and could be compared with field measurements.

A true triaxial test facility described in the International Journal for Rock Mechanics and Mining Science (Vol. 18, pp. 129-140, 1981) was developed in 1975 to investigate the time-dependent failure processes of underground openings in brittle, naturally jointed rock. It has been used for several research contracts since then. Field pressure of 15 MPa can be applied to all sides of the sample and maintained with pressure variations of less than 1% for long periods of time (weeks or months). Circular openings can be excavated under stress and radial strain and convergence measurements can be recorded electronically. Computer programs are available for data processing.

A high-pressure pressuremeter manufactured by Mazier et Cie. in France has been used by the University of Alberta to a depth of 103 m. It consists of a steel-reinforced rubber membrane that can be pressurized up to 20 MPa (design pressure; but 30 MPa can be achieved after some minor modifications). Good quality boreholes are required for high-pressure testing. The probe is designed for a 96 mm hole and for rock with a deformation modulus of less than 7500 MPa. The borehole diameter change is monitored in three directions at measuring points that are in direct contact with the surrounding rock. The measuring range is 25 mm at each contact point, allowing expansion of the borehole to 140 mm. At very high pressures, however, it is seldom possible to carry out tests to this limit because excessive membrane distortion may lead to sealing problems. The sensitivity is ±10 microns.

5. CONCLUDING REMARKS

W.E. Taylor,
Potash Corporation of Saskatchewan, Saskatoon

I should point out, Gentlemen, that I am standing up not necessarily as the Research Mining Manager for PCS, but also as a member of the National Advisory Committee of Mining and Metallurgical Research, which gives advice about the general direction of CANMET research.

About four years ago Dr. P. Mottahed and I went to Ottawa and asked CANMET if they could please come and give some attention to the Saskatchewan Potash Industry. This was before the decision had been made to proceed with the New Brunswick operation. We asked CANMET if they would come here and assist with some of the mutually beneficial basic research programs that could eventually be beneficial to the whole of the industry. We have gone from having literally no technical exchange within the industry, because of proprietary interests of the various companies, to a time like today when 43 of us can sit around the table and listen to a technical exchange of presentations made by various experts - including consultants, CANMET, industry in general, and universities. This is a great stride forward. I see here for the first time some companies that have never sat down at the table to even listen to some of the technical problems that we all mutually experience. With this in mind, I have to remind the mining companies, or the mining company representatives who are here today, that when you leave the room and go back to your own operations you should take with you your impressions of what CANMET and CANMET's research projects can do for the Saskatchewan potash industry.

The Law of Gravity is the same for all our companies, and some of the basic research projects that we have reviewed here today are applicable to all of us. I know that each one of us has today learned more about the technical problems that the industry is facing. Today, the expert consultants and project leaders have expressed how their projects are progressing. I would like to thank CANMET on behalf of the NACMMR Committee for the way it has responded to the NACMMR Committee's concerns for this specific branch of the mining industry. This is an excellent follow up to an industry specific request.

Gentlemen, as the end users of this information, I would ask that as you go back to your companies you remember that the potash industry (and I'll say in Canada, because we have to include New Brunswick) can only exist as long as we can sell, on the world market, the most economically produced product. If the price of potash goes too high, we bring every high-cost producer back into the picture. So, only by taking advantage of good R & D can we continue to be good low-cost producers and suppliers of a product for the farmers of the world. Remember that R & D exists for one purpose only in our industry, and that is to make the cost of fertilizer the lowest possible for the farmer. If anyone else can supply it cheaper than we can, they will do so and we will lose, and our bread and butter will go out the window.

I must say that I am pleased to see a representative from the Federal Republic of Germany here today. When our industry started in Saskatchewan, we were lucky enough to be able to go to Germany and many of the engineers in that country, who had years of experience in the potash industry, shared many, many

technical sessions with us and also shared their information, for which we thank them. Let us share our basic information here as an industrial group. Make sure that the exchange is freely given. If information is proprietary, say so, there is nothing wrong in being competitive in our market, God knows we are all competitive enough. But also, make sure that we, the Saskatchewan potash industry, use the facilities of CANMET (for which we are taxed) to its maximum ability. Let's make sure that if there is one problem we can mutually attack, we all use CANMET as a neutral vehicle to attack the technicalities of the problem in order to come up with an answer.

I am very pleased with the group at C.C.P. which is working with Dr. Mottahed of PCS on the backfill problem in the water bearing area; this is excellent industrial cooperation. Some of the information that is coming back to PCS as a result of this CANMET/Industry Project is the best information that we have layed our hands on. So again, Gerhard (Dr. G. Herget), I congratulate you on the way you have put your project review together. On behalf of the NACMMR Committee, I thank you all very much for the information exchanged and the technical details that have passed across the table today, and I am very pleased that you were all able to attend this seminar.

Thank you very much indeed.

5. CONCLUSION

W.E. Taylor,
Potash Corporation of Saskatchewan, Saskatoon

Messieurs, c'est non seulement en tant que directeur des recherches minières de la PCS que je m'adresse à vous, mais aussi en tant que membre du Comité consultatif national de la recherche minière et métallurgique, qui conseille le CANMET sur l'orientation générale à donner aux recherches.

Il y a environ quatre ans, M. P. Mottahed et moi sommes allés à Ottawa pour demander au CANMET de bien vouloir venir en Saskatchewan pour examiner la situation de l'industrie de la potasse. Cette démarche a eu lieu avant que cette industrie se développe au Nouveau-Brunswick. Nous avons demandé au CANMET de nous aider par quelques programmes de recherche de base qui pourraient nous profiter mutuellement et qui pourraient tôt ou tard profiter à toute l'industrie. Par le passé, les différentes sociétés au sein de l'industrie n'échangeaient littéralement aucun renseignement technique pour protéger leurs intérêts respectifs; aujourd'hui nous sommes 43 assis autour de la même table pour participer à un échange technique en écoutant les présentations de divers experts, de firmes, du CANMET, de l'industrie en général et des universités. Un grand pas a été franchi. Je peux voir ici pour la première fois des représentants de sociétés qui ne se sont jamais rencontrés, ne serait-ce que pour prendre connaissance de certains problèmes techniques qui nous touchent tous. Gardant ceci à l'esprit, je dois rappeler aux sociétés minières ou à leurs représentants ici présents de ne pas oublier, en quittant cette salle, tout ce que le CANMET et ses projets de recherche peuvent apporter à l'industrie de la potasse de la Saskatchewan.

La loi de la pesanteur est la même pour toutes nos sociétés et certains des projets de recherche de base qui ont été examinés aujourd'hui sont applicables à nous tous. Je sais que chacun d'entre nous a beaucoup appris au sujet des problèmes techniques auxquels fait face notre industrie. Aujourd'hui, les experts-conseils et les chefs de projet ont expliqué où en étaient leurs projets. Je voudrais remercier le CANMET au nom du Comité consultatif national de la recherche minière et métallurgique pour la façon dont il répond aux préoccupations de ce Comité à l'égard de cette industrie minière particulière. Il s'agit là d'une excellente façon de répondre à une demande spécifique d'une industrie.

Messieurs, en tant que utilisateurs finals de ces renseignements, j'aimerais vous demander de ne pas oublier en retournant dans votre entreprise que l'industrie de la potasse (je dirais au Canada, si on inclut le Nouveau-Brunswick) ne peut exister qu'aussi longtemps qu'elle puisse vendre, sur le marché mondial, un produit dont le prix de revient est le plus bas possible. Tout producteur de potasse dont le prix sera trop élevé sera éliminé par ses concurrents. Ainsi, ce n'est qu'en mettant à profit des efforts éclairés de R-D que nous pourrons continuer à produire à un faible coût des produits destinés aux agriculteurs du monde entier. Rappelez-vous que l'unique but de la R-D est de permettre à notre industrie de vendre des engrais au plus bas prix possible aux agriculteurs. Si un concurrent peut les fournir à meilleur prix, il le fera et nous perdrons notre gagne-pain.

Je dois mentionner qu'il me fait plaisir de voir ici un représentant de la République fédérale d'Allemagne. Lorsque notre industrie en était à ses débuts en Saskatchewan, nous avons eu la chance d'aller en Allemagne; nous y avons rencontré beaucoup d'ingénieurs, forts d'une longue expérience dans l'industrie de la potasse, avec lesquels nous avons participé à de nombreuses sessions techniques et qui nous ont transmis leur savoir, ce dont nous les remercions. C'est à notre tour de partager sans restriction notre information de base en tant que groupe industriel. Si des renseignements sont privés, disons-le; il n'y a rien de mal à être compétitif dans notre marché, mais Dieu sait que nous le sommes tous suffisamment. De même, n'hésitons pas, nous de l'industrie de la potasse de la Saskatchewan, à utiliser au maximum les installations du CANMET (pour lesquelles nous payons des impôts). Rassurons-nous que s'il y a un problème auquel nous pouvons nous attaquer ensemble, nous utiliserons le CANMET comme véhicule neutre pour trouver une réponse aux aspects techniques du problème.

Je souligne avec grand plaisir l'excellent travail de collaboration industrielle entre le groupe du C.C.P. et M. Mottahed du PCS sur le problème du remblayage dans les zones aquifères. Une partie des renseignements fournis au PCS sous forme de résultats de ce projet CANMET/Industrie sont les meilleurs que nous n'ayons jamais eu en nos mains. À nouveau Gerhard (G. Herget), je vous félicite pour la manière dont vous avez mené votre étude. Au nom du Comité consultatif national sur la recherche minière et métallurgique, je vous remercie tous beaucoup pour les renseignements et détails techniques échangés à cette table aujourd'hui et je suis très heureux que vous ayez pu être présents à ce séminaire.

Merci beaucoup encore une fois.

6. CLOSING REMARKS

Dr. J.E. Udd,
Director Mining Research Laboratories, CANMET, EMR

Ladies and gentlemen, it is a great pleasure to have the opportunity to say a few words following Blue Taylor's eloquent remarks. On behalf of CANMET I would like to express our thanks for these, and for the expression of confidence in our organization. Our role is to provide research assistance to the industry and it is very encouraging to hear that both our and your objectives are being met. The comments concerning our neutrality in performing and sponsoring research are significant. It is to be hoped that the industry will take note of these.

From a personal point of view, I have found the sessions both educational and informative. Most of the work which has been reported at this meeting predates my joining CANMET only a few months ago. Consequently, the presentations have given me an appreciation of the needs of the potash industry for mining research as well as of the work which has been done, and of desired future directions.

This meeting is the second of this kind of technology transfer sessions that the Mining Research Laboratories have organized in the past few months. Both it, and its predecessor, on Rockbursts, in Sudbury, last August, were well attended. I hope that there will be many such sessions, on a variety of topics, in the future. These meetings are an excellent means of maintaining contact with each other and of sharing information. As Blue Taylor has mentioned, it is significant that, for the first time, today there are representatives of all of the producers present in this room.

The work which has been reported at this meeting, as you know, has been funded through the START program. That program is now drawing to a conclusion and, as a result, the present level of our involvement with potash mining research cannot be sustained. We do, however, wish to continue with as many of the follow-up studies as our resources will allow. In that respect, your comments and opinions on the needs for future research will be most useful to us for our own planning purposes. We invite you to arrive at a consensus and to make your needs and opinions known to us.

Having listened to the presentations, and believing that these should be given the broadest possible circulation, my colleagues and I have decided that these should be the subject of a special Divisional report. This follows the precedent that was established for the Proceedings of the Microseismic Workshop that was held in Sudbury. Bob Blake of our Technical Information Division is now bringing that publication towards completion, and is preparing himself for a second request!

In essence, we plan to publish the full texts of the original contributions, in the languages in which these were presented. As is our usual policy, the abstracts, the index, and the opening and closing remarks, will be published in both official languages. All of those who have contributed are invited to arrange for their texts to be delivered to Gerhard Herget as soon as possible. I hope that we can arrange to have the publication well in

hand by the end of this fiscal year. Your cooperation on that would be appreciated. Written comments and discussions are also invited.

In closing, I would like to thank Gerhard for coordinating the organization of the projects and for organizing today's session; I would ask you to join me in expressing our appreciation to him.

6. MOT DE LA FIN

J.E. Udd
Directeur des Laboratoires de recherche minière, CANMET, EMR

Mesdames et messieurs, c'est avec grand plaisir que je vous adresse ces quelques mots après les remarques éloquentes de Blue Taylor. Au nom du CANMET, je voudrais vous en remercier et souligner la confiance que vous avez témoignée à notre égard. Notre rôle est de fournir à l'industrie un service de recherche et il est très encourageant d'entendre que vos objectifs, ainsi que les nôtres, sont en voie d'être atteints. Les commentaires concernant notre impartialité dans la conduite et le parrainage des recherches sont significatifs. Il serait souhaitable que l'industrie en prenne note.

Personnellement, j'ai trouvé les sessions très instructives. La plupart des travaux dont il a été fait état lors de cette réunion sont antérieurs à mon arrivée au CANMET qui ne date que de quelques mois. Par conséquent, les présentations m'ont permis d'apprécier les besoins de l'industrie de la potasse en recherche minière ainsi que les travaux déjà faits et les orientations à donner aux recherches futures.

Cette rencontre est la seconde du type "séance de transfert de technologie" que les Laboratoires de recherche minière ont organisées au cours des quelques derniers mois. La participation à cette réunion, ainsi qu'à celle de Sudbury sur les coups de toit en août dernier, a été nombreuse. J'espère qu'il y aura encore beacoup de séances semblables traitant d'une variété de sujets. Ces réunions sont un excellent moyen pour nous rencontrer et échanger des renseignements. Comme Blue Taylor l'a mentionné, il est important de constater qu'aujourd'hui, pour la première fois, tous les producteurs sont représentés dans cette salle.

Comme vous le savez, les travaux dont il a été fait état lors de cette réunion ont été financés dans le cadre du programme START. Comme le programme tire à sa fin, il ne nous sera plus possible de maintenir notre niveau actuel d'engagement dans la recherche sur l'exploitation minière de la potasse. Nous souhaitons toutefois continuer à suivre autant d'études que possible dans la mesure de nos ressources. À cet égard, il nous serait très utile de recueillir vos commentaires et les opinions du groupe sur les besoins futurs en matière de consensus et à nous faire connaître vos besoins et vos opinions.

Nous avons écouté les présentations et, convaincus qu'il faut leur donner la plus grande diffusion possible, nous avons décidé, mes collègues et moi, d'en faire le sujet d'un rapport de division spécial comme dans le cas du Compte rendu de l'Atelier sur la microsismique tenu à Sudbury. Bob Blake de notre Division de l'information technologique est sur le point d'achever cette publication et se prépare à recevoir une seconde demande!

En essence, nous prévoyons de publier les textes complets des contributions originales dans la langue de leur présentation. Selon notre politique habituelle, les résumés, les index, les introductions et les conclusions seront publiées dans les deux langues officielles. Tous les collaborateurs sont invités à remettre leur texte à Gerhard Herget aussitôt que possible. J'espère que nous pourrons nous arranger pour que les publications soient en ses mains

à la fin de l'année financière. Votre coopération serait très appréciée. Vous êtes invités aussi à nous faire part de vos commentaires et de vos discussions par écrit.

Pour conclure, je voudrais remercier Gerhard pour avoir coordonné les projets et organisé la séance d'aujourd'hui. Je voudrais vous demander de vous joindre à moi pour lui exprimer notre reconnaissance.

APPENDIX A

ANNEXE A

POTASH PROJECT

Final Contract Progress Review and Technology Transfer Seminar

Will Inns, Saskatoon
(306) 665-6500
November 21, 1984 - 8:30 a.m.

Participants: Contractors (2 representatives maximum) and scientific authorities.

Presentation: 20 minutes by contractors, followed by 15 minute question period, overhead projector and 35 mm Kodak slide projector will be provided

A G E N D A

Chairman: G. Herget, Project Leader, Mining Research Laboratories.

8:30 Introduction

8:40 MONENCO - Mining Options for potash.
Scientific Authority: J. Pathak

9:15 PCS - Regional mine stability.
Scientific Authority: M. Gyenge

9:50 Coffee.

10:10 SRC - Creep testing facility.
Scientific Authority: L. Geller

10:45 RE/SPEC - Numerical modelling of excavations in potash.
Scientific Authority: Y. Yu

11:20 RE/SPEC - Engineering properties of waste salt as a backfill.
Scientific Authority: M. Bétournay

11:55 Lunch

13:15 Cominco - Absolute convergence measurements in potash.
Scientific Authority: G. Herget

13:50 CCP - Sealing and backfilling of water inflow.
Scientific Authority: G. Herget

14:25 Coffee

14:45 Cambrian Engineering - Dust in potash operations.
Scientific Authority: G. Knight

15:20 Other business.

POTASH MINING - 310104

Attendance at seminar in Saskatoon on November 21, 1984:

Industry representatives and contractors

Mr. W.E.G. Taylor, PCS - representing National Advisory Committee of Mining and Metallurgical Research (NACMMR)

Dr. G. Strathdee, PCS - representing Saskatchewan Mining Association

Dr. H. Tammemagi, RE/SPEC, Calgary, Alberta

Mr. A. Scott, Monenco, Calgary, Alberta

Mr. J. Sadler, Vice President, PCS Mining, Saskatoon

Dr. P. Mottahed, Potash Corporation of Saskatchewan (PCS), Saskatoon

Dr. M. Reeves, University of Saskatchewan, Saskatoon

Mr. A.S. Middleton, Cambrian Engineering, Saskatoon

Dr. W.F. Bawden, Noranda Mines, Pointe Claire, P.Q.

Mr. D. Mackintosh, Cominco Ltd., Vanscoy, Saskatchewan

Dr. R. Arnold, Saskatchewan Research Council (SRC), Saskatoon

Dr. K. Yoshida, SRC for Cambrian Engineering, Saskatoon

Mr. J. Ball, PCS, Saskatoon

Mr. J. Jones, SRC, Saskatoon

Mr. R. Beddoes, RE/SPEC, Calgary, Alberta

Mr. D.S. Boyle, Cominco Ltd., Vanscoy, Saskatchewan

Mr. K.M. Pawliuk, Cominco Ltd., Vanscoy, Saskatoon

Mr. N. Martin, Potash Corporation of America, Saskatoon

Mr. W. H. Webster, Potash Corporation of America, Saskatoon

Mr. G. McLaughlin, Potash Corporation of America, Saskatoon

Mr. W. Cusitar, Mraz Project Consultants, Saskatoon

Mr. D. Mraz, Mraz Project Consultants, Saskatoon

Mr. G. Phillips, I.M.C., Esterhazy, Saskatchewan

Mr. J. Lewis, I.M.C., Esterhazy, Saskatchewan

Mr. E. Seidler, I.M.C., Esterhazy, Saskatchewan

Mr. R. Plosz, Kalium Chemicals, Regina, Saskatchewan

Mr. A.M. Coode, Central Canada Potash, Colonsay, Saskatchewan

Mining Research Laboratories

Mr. M. Bétournay, Mr. L. Geller, Mr. M. Gyenge, Dr. G. Herget, Mr. G. Knight, Dr. J. Udd, Mr. Y.S. Yu

EMR CANMET

Dr. T. Aston, Mr. G. Barry, Mr. R.T. Blake, Mr. D.B. Gladwin, Ms. Justyna Kuryllowicz, Mr. G. Zahary

Other

Dr. M. Dusseault, University of Waterloo, Waterloo, Ontario

Dr. P.K. Kaiser, University of Alberta, Edmonton, Alberta

Dr. A. Pahl, BGR, Hannover, West Germany

Mr. G.B. Lopez, Sask. Energy and Mines, Regina, Saskatchewan

Mr. J. Chandra, New Brunswick Dept. of Natural Resources, Fredericton, New Brunswick

Mr. J. Hayward, Sask. Environment, Regina, Saskatchewan

Mr. P.E. Rosen, Sask. Dept. of Labour, Saskatoon, Saskatchewan

OPINION SURVEY:

PLEASE EXPRESS YOUR OPINION (Nov. 21/84)

Name: **Address:**

Company: **Telephone No.:**

How would you like to see the potash mining research effort continued?

Discontinue:	Yes	No
Continue:	Yes	No
Would you be interested in participating in R & D effort?	Yes	No

Option 1: develop special expertise in:	not needed	useful	most desirable
Backfilling			
Ground control instrumentation			
Brine or water locating devices			
Shaft lining quality assessments			
Numerical modelling			
Subsidence studies			

Please specify others:

Option 2: Carry out a comprehensive study to come up with an improved potash mining method:

Technology transfer:
Summary report and microfiche of full reports

General presentation at mine site

Specialty seminars on topics like: numerical modelling, instrumentation, backfilling, other (please specify)

Remarks

PROJET SUR LA POTASSE

Séminaire sur le transfert de technologie et examen final de l'avancement des contrats finals

Will Inns, Saskatoon
(306) 665-6500
21 novembre 1984, 8 h 30

Participants: Entrepreneurs (maximum 2 représentants) et autorités scientifiques

Présentation: 20 minutes par entrepreneur, suivies d'une période de questions de 15 minutes; un rétroprojecteur et un projecteur à diapositives Kodak 35 mm seront fournis.

ORDRE DU JOUR

Président: G. Herget, Chef de projet, Laboratoires de recherche minière.

8 h 30	Introduction
8 h 40	MONENCO, Possibilités d'exploitation minière de la potasse. Autorité scientifique: J. Pathak
9 h 15	PCS - Stabilité régionale des mines. Autorité scientifique: M. Gyenge
9 h 50	Café
10 h 10	SRC - Installations d'essai de fluage Autorité scientifique: L. Geller
10 h 45	RE/SPEC - Propriétés techniques du sel résiduel comme remblai. Autorité scientifique: M. Bétournay
11 h 55	Déjeuner
13 h 15	Cominco - Mesures de convergence absolue dans la potasse. Autorité scientifique: G. Herget
13 h 50	CCP - Obturation et remblayage des venues d'eau. Autorité scientifique: G. Herget
14 h 25	Café
14 h 45	Génie du Cambrien - Poussière dans les mines de potasse. Autorité scientifique: G. Knight
15 h 20	Divers.

EXPLOITATION DE LA POTASSE - 310104

Participation au séminaire, à Saskatoon, le 21 novembre 1984:

Représentants de l'industrie et entrepreneurs

M. W.E.G. Taylor, PCS - Représentant du comité consultatif national de la recherche minière et métallurgique (NACMMR)

G. Strathdee, PCS - Représentant la Saskatchewan Mining Association

H. Tammemagi, RE/SPEC, Calgary (Alberta)

A. Scott, Monenco, Calgary (Alberta)

J. Sadler, Vice-Président, PCS Mining, Saskatoon

P. Mottahed, Potash Corporation of Saskatchewan (PCS), Saskatoon

M. Reeves, Université de la Saskatchewan, Saskatoon

A.S. Middleton, Cambrian Engineering, Saskatoon

W.F. Bawden, Mines Noranda, Pointe-Claire (Qc)

D. Mackintosh, Cominco Ltd., Vanscoy (Saskatchewan)

R. Arnold, Saskatchewan Research Council (CRS), Saskatoon

K. Yoshida, SRC for Cambrian Engineering, Saskatoon

J. Ball, PCS, Saskatoon

J. Jones, SRC, Saskatoon

R. Beddoes, RE/SPEC, Calgary (Alberta)

D.S. Boyle, Cominco Ltd., Vanscoy (Saskatchewan)

K.M. Pawliuk, Cominco Ltd., Vanscoy, Saskatoon

N. Martin, Potash Corporation of America, Saskatoon

W.H. Webster, Potash Corporation of America, Saskatoon

G. McLaughlin, Potash Corporation of America, Saskatoon

W. Cusitar, Mraz Project Consultants, Saskatoon

D. Mraz, Mraz Project Consultants, Saskatoon

G. Phillips, I.M.C., Esterhazy (Saskatchewan)

J. Lewis, I.M.C., Esterhazy (Saskatchewan)

E. Seidler, I.M.C., Esterhazy (Saskatchewan)

R. Plosz, Kalium Chemicals, Régina (Saskatchewan)

A.M. Coode, Central Canada Potash, Colonsay (Saskatchewan)

Laboratoires de recherche minière

M. Bétournay, L. Geller, M. Gyenge, G. Herget, G. Knight, J. Udd, Y.S. Yu

EMR, CANMET

T. Aston, G. Barry, R.T. Blake, D.B. Gladwin, Justyna Kuryllowicz, G. Zahary

Autres

M. Dusseault, Université de Waterloo, Waterloo (Ontario)

P.K. Kaiser, Université de l'Alberta, Edmonton (Alberta)

A. Pahl, BGR, Hanovre, Rép. féd. d'Allemagne

G.B. Lopez, Sask. Energy and Mines, Régina (Saskatchewan)

J. Chandra, New Brunswick Dept. of Natural Resources, Fredericton (N-B)

J. Hayward, Sask. Environment, Régina (Saskatchewan)

P.E. Rosen, Sask. Dept. of Labour, Saskatoon (Saskatchewan)